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Assessment of the scallop stock in Scallop Production Area 1, Bay of Fundy for the fall of 1999

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Abstract

Starting on 1 January 1997, the Bay of Fundy scallop fishery was divided into Scallop Production Areas (SPA's) for management considerations. This move was made in response to declining catches and concerns over the long term viability of the scallop fishery. SPA 1 is the largest SPA in the Bay of Fundy, and is accessible, at least in part, to all Bay of Fundy scallop license holders. This assessment examines survey data, logbook data, and the Full Bay fleet port sampling data.

Survey biomass estimates and commercial catch rates declined from the historic peak in 1988/89, to the lowest levels in either time series in 1997. Since that time they have improved slightly, but are still at low levels. At the present level of effort the removals from the stock in the traditional Digby and Cape Spencer areas appear to be less than growth and recruitment, allowing for a slight increase in the population. The outlook is for a stable but low scallop abundance in this area, as long as fishing effort remains at present levels.

Résumé

Depuis le 1er janvier 1997, on a divisé la pêche du pétoncle dans la baie de Fundy en zones de production de pétoncle (ZPP), à des fins de gestion. Cette décision a été motivée par le déclin des prises et par des inquiétudes quant à la viabilité à long terme de la pêche du pétoncle. La ZPP1 est la plus grande ZPP de la baie de Fundy; elle est accessible, au moins en partie, à tous les titulaires de permis de pêche du pétoncle dans la baie de Fundy. Dans la présente évaluation, on examine les données de relevé, les journaux de bord et les données d'échantillonnage au port de la flottille qui pêche dans la totalité de la baie. En 1997, les estimations de biomasse selon le relevé et les taux de prises commerciales ont diminué par rapport au sommet historique qu'ils avaient atteint en 1988-1989 et sont tombés au plus bas niveau des deux séries chronologiques en 1997. Depuis lors, ils se sont légèrement améliorés, mais restent bas. Au niveau actuel d'effort, les retraits dans le stock des zones d'exploitation traditionnelles de Digby et du cap Spencer semblent inférieurs à la croissance et au recrutement, ce qui permet une légère augmentation de la population. On envisage une abondance stable, mais faible, des pétoncles dans ce secteur, tant que l'effort se maintiendra à son niveau actuel.

Introduction

Commercial scallop fishing in the Bay of Fundy was first reported by W.F. Ganong in 1889 (Ganong 1889), who reported that about 200 bushels originating from Maces Bay and L'Etang Harbour were sold annually in Saint John. In the 1920's, a commercial fishery started in Annapolis Basin N.S., where Lescarbot had first reported scallops in 1609 (Lescarbot 1609). This fishery quickly moved out into the productive grounds off Digby, Nova Scotia. Scallop fishing regulations were first initiated in 1918 with licenses, a minimum size and closed seasons. These types of regulations are still in use for this fishery. Special regulations for specific areas within the Bay of Fundy date back to 1939 when a restriction on gear width was introduced specifically for Grand Manan waters. On the Nova Scotia side, a special zone was created off Digby in 1952, with a closed season from May 1 to September 30 to provide an area close to port for the winter fishery.

On January 1, 1997, in response to declining catches and concerns over the long term viability of the fishery, the Bay of Fundy was divided into Scallop Production Areas (SPA's) for better management (Figure 1).

Scallop Production Area 1 in the Bay of Fundy is a large area encompassing several different fishing grounds, and is accessible by three different scallop license categories (Table 1). Full Bay scallop licenses are able to fish scallops anywhere in the Bay of Fundy and are usually held by larger vessels (>25.5 Gross Tons). Mid Bay license holders can fish for scallops on the northern side of the Mid Bay line (Figure 1), and Upper Bay license holders east of the Upper Bay line. These last two categories of licenses are typically held by smaller multi-purpose vessels that fish local waters.

Current regulations for this fishery consist of:

Limited entry.
Restrictions on gear type - no offshore or green sweep drags (single wide styles of drags) .
Maximum width of gear - 5.5 m
Minimum ring size - 82 mm.
Meat count (Average number of meats/500 g) - 45/500g.
Minimum shell size - 95 mm.
Total Allowable Catches, either as individual vessel quotas in the Full Bay Fleet or an overall allowable catch for the Mid and Upper Bay fleets.
Hail in upon leaving port and 2 hours before landing.
Dockside monitoring of catches.
Required to keep a Logbook (Scallop Monitoring Document) reporting location catch and effort.
Special seasons, i.e. for a 2-mile conservation zone along the New Brunswick coast, 1-mile closure along the Digby Neck. In 1998 there was also a closure of SPA 1 to the Full Bay fleet when SPA 4 was open, to help in enforcement.

Landings in SPA 1 have increased from the low in 1997, and for January to October 10, 1999 were 194 t for the Full Bay vessels, 47 t for the Mid Bay vessels and 17 t for the Upper Bay vessels. This was a 12 % increase in landings over 1998 and 81 % over 1997, with a few more landings to come in the rest of the year. The allowable catch for the Mid and Upper Bay fleets was reached, and the fishery closed on August 29th this year, but the fishery was reopened for September 2 to October 16, under the condition that a port sampling program be implemented.

The main concentration of scallops in SPA 1 is a bed that runs between Centerville and Hampton on the Nova Scotia side, over towards Cape Spencer on the New Brunswick side. This bed is divided into SPA's 1 and 4, and by the Mid Bay line. The largest portion is on the Nova Scotia side of the Mid Bay line, and is accessible only to the Full Bay fleet, while that on the New Brunswick side is accessible to both the Mid and Full Bay fleets. There are several smaller grounds further up the Bay, including those fished by the Upper Bay fleet.

There is no survey covering the entire SPA 1, but there are productive portions that have had multiple surveys over time. The SPA boundaries cut through an area that has a long time series of annual surveys (Figure 2). Although the survey areas are not an exact match to the new SPA boundaries, it was felt that the match was close enough that it would be better to retain the consistency of the surveys than to alter their format.

Surveys used in this assessment are the annual surveys in the "2-16 mile" section from Sandy Cove to Hampton, excluding Area 4; several older surveys and recent annual ones

covering the section from 16 miles going towards Cape Spencer, New Brunswick; and three recent surveys that were carried out in the Upper Bay.

Data Availability:

Research surveys

There have been annual surveys of the Digby portion of SPA 1 since 1978 (Kenchington et al. 1995). The Cape Spencer grounds were first surveyed in 1987, (Chandler et al. 1989) during a survey of the Northern side and Upper Bay area. Robinson and Chandler (1990) and Robinson *et al.* (1992) conducted surveys covering the Cape Spencer area in 1989, 1990 and 1991. Annual surveys of the Cape Spencer area were initiated with grid surveys in 1996 and 1997, in conjunction with the stratified random surveys of the 2-16 mile Digby area. The design was changed to a random survey in 1998. The Upper Bay area was surveyed in 1986-87 (Chandler et al., 1989), and in conjunction with studies on the effects of opening the Peticodiac River causeway in 1998 (Kenchington et al., 1998) and twice in 1999.

Logbooks

Logbooks were required for vessels >25 gross tonnes (G.T.) starting in 1973. In 1979 the requirement was changed to vessels > 25.5 G.T. or > 14 m Length Over All (LOA). These requirements covered most of the Full Bay license holders but few of the Mid Bay or Upper Bay licenses, although some of these vessels submitted logbooks. In the Full Bay Fleet, the percentage of active licenses that submitted logs has varied from 14 to 100%. The Mid Bay and Upper Bay license holders agreed to complete logbooks on a voluntary basis in 1996 and logbooks became mandatory in 1997.

There are still problems with the quality of the Mid and Upper Bay log data. There are many cases in which the effort and landings do not seem to correspond; i.e. catch rates exceeding 200 pounds an hour. Part of the problem appears to result from a fishing pattern of making day trips to fish, but only selling the catch periodically. The weighout is recorded on the current page of the logbook, and the effort from earlier trips is either never recorded, or the pages without the weighout are lost from the system.

In some cases the problem is obvious, i.e. the estimated catch weight that the fisher enters for each day's fishing on the log is less than half the actual weighout. These cases have been given a data class code so that they are not included in the calculations of CPUE. There are many more records that can be selected on the basis of abnormally high catch rates, but there comes a point when the decision on what is abnormal becomes subjective and influences the trends in the data. The log data used here has been edited to remove extreme values, but the results should be used with caution.

Port sampling

Port samples were collected regularly from the Full Bay Fleet landing in Nova Scotia, but there had been no port sampling program covering the Mid Bay or Upper Bay Fleets in SPA 1. There were occasional Mid Bay port samples from an industry program targeted at SPA 6, and in October of 1999, a port sampling program was initiated in conjunction with an extension of the allowable catch limit for the Mid and Upper Bay fleets. Most of the samples from this program came from the Upper Bay area, while most of the available Full Bay samples come from the 2-16 mile Digby Area.

Methods

The survey analysis was divided into separate areas. The first was the area 2-16 miles off the Nova Scotia shore from Sandy Cove to Hampton, for which a time series of surveys exists. Annual surveys of this area have been conducted since 1978, but the station allocation scheme and area covered has changed during this period. For a full description of these changes see Kenchington et al. (1995). For this reason, the 1991 to 1999 surveys, which are of a consistent area and with the most consistent design, will be the main ones used for this analysis, with the older surveys used to look at longer-term trends. The survey area is now split between SPA 1 and SPA 4, which extends out to 8 miles from Sandy Cove to Parkers Cove (Figure 1). The SPA 1 survey was therefore broken down into two sections, the 8-16 mile area from Sandy Cove to Hampton, and a 2-8 mile area above SPA 4 (Figure 2).

Tows of approximately 8 minutes duration were carried out at each randomly assigned station with a set of 4 Digby buckets (0.762 meters wide, 76 mm rings with rubber washers), 2 lined and 2 unlined. The catch of scallops in the lined (38 mm diagonal mesh liner) was used to

estimate the catch of scallops <80 mm shell height, and the catch in the unlined buckets was used for scallops ≥ 80 mm shell height. Catches were standardized to an 800 m tow with a 7 bucket drag (800 m * 5.334 m = 4,267.2 m^2). Trends are examined in both stratified mean numbers of scallops per standard tow, and in mean scallop meat weight per standard tow. The strata used in the stratification of the 8-16 mile zone can be seen in Figure 2, with the number of stations assigned on the basis of strata area and variance.

A separate analysis was conducted for the Cape Spencer area, for which there is an irregular series of surveys covering different areas, and with differences in the way they have been conducted. Surveys tows were again standardized to an 800 m tow with 7 buckets. Catches from older surveys that had been recorded in round weight were converted to meat weights by dividing by the conversion factor of 8.33, which is the conversion factor used by Statistics Branch. Station assignments were on a grid in 1987, 1996 and 1997, and randomly assigned in 1989, 1990, and 1991 and since 1998. Since the area surveyed varied from year to year, biomass estimates were calculated both for the entire survey area and for a polygon that was surveyed in all 8 years. The abundance estimates within this polygon were used to examine trends in biomass. Biomass was estimated by contouring using delauny triangulation, which does not provide confidence intervals, and with an arithmetic mean estimate, for which confidence intervals can be calculated.

In the Upper Bay area the 1986-1987 survey was described in Chandler et al. (1989). Data was only available in summary form from this survey and so the closest match to the later survey areas were the numbers per standard tow for unlined drags. This will contain some scallops less than 80 mm shell height but there was no data available for height frequencies on a tow by tow basis. The data is included here for comparison with the latter surveys with the caution that the numbers are not directly comparable but the distribution is. The 1998 and 1999 surveys were conducted by commercial vessels using 8, 2 foot wide "Miracle drags". Drags 1 and 5 were lined with 38 mm diagonal mesh, and all were made with 78 mm rings and rubber washers. The same protocols as used in the other surveys were followed for the Upper Bay surveys. Mean numbers per standard tow and shell height frequencies were used to compare surveys and the survey results were used to produce contour maps of numbers per standard tow with the ACON package.

CPUE's for SPA 1 were calculated from the Full Bay logs for the 1976 to 1999 period, and the Mid Bay and Upper Bay logs for 1992-1999.

Port sampling data for the Full Bay fleet was broken down into areas corresponding to the survey analysis; <8 miles from shore above SPA 4; 8-16 miles offshore from Sandy Cove to Hampton; and the remainder of SPA 1. To examine changes in the size distribution of the catch with time, the meat weight frequencies by month were plotted for 1996 to 1999. The September port samples from the new program for the Mid and Upper Bay fleets were plotted for comparison to the Full Bay samples.

A preliminary estimate of exploitation rate was done using a Leslie depletion estimator as for the Area 4 scallop assessment (Smith et al. 1999a). This estimator makes the following assumptions about the data.

1. Catchability of the fished population is constant over a fishing season.
2. Fishing effort is uniformly distributed over the area occupied by the stock.
3. The population is closed and has no movement in or out and no natural mortality during the fishery.
4. Landings and effort are reported accurately.

The first step in examining this estimator was to select only log records from the 8-16 mile zone (Figure 2). Location of fishing was provided for the first tow of each day during a fishing trip. Only logbooks for 1999 were examined in this preliminary analysis.

Mean weights were not estimated for this area. Only survey sampling was available to estimate mean weights. Relating these to the fishery would involve applying a constant to the fishery catches. As a result, it was decided to evaluate the results of a preliminary analysis based on weight of catch, before attempting to estimate numbers using survey biological sampling.

The analysis proceeded by summing catch and effort, for all boats by day. This method differs from the analysis of Areas 3, 4, and 7 (Smith et al. 1999ab) which summed the catch and effort for each trip and then summed days according to the last day of each trip. Summing by trip is preferable because the catch data is collected by trip, but it is more time consuming to calculate and so for this preliminary analysis the simpler method was chosen.

The first step was to produce cumulative plots of the catch to look for breaks in the fishery that would correspond to shorter time periods. Short time periods are important for satisfying the assumptions associated with distribution of fishing effort, constant catchability, and little or no immigration or emigration.

From this analysis three time periods were identified: January 4 to March 6; March 18 to May 28, and July 5 to September 22. Separate analyses were done for each of these periods.

Results

Traditional Area surveys

Based on the mean number of scallops <80 mm per standard tow for the 10 strata in the 8-16 mile survey (Table 2), there was an indication of improved recruitment centered on the Digby Gut area. It was more wide spread than the isolated patches seen in recent years. In the North-East side, (Parkers Cove to Hampton) the population was continuing to decline. This pattern was seen to a lesser degree in the >80 mm size class, with the Centerville to Digby Gut area showing an increase, while the Delaps Cove to Hampton end was decreasing (Table 3).

The plots of mean numbers by year (Figure 3) show the low level of recruitment. There was a non-significant increase in the mean numbers per standard tow in 1999 (Tables 4 and 5). When mean numbers and mean weight were compared (Figure 4) the mean numbers per tow showed a larger increase than the mean weight since the low of 1996-1997, indicating a decrease in the mean size.

The 2-8 mile section (Table 6) showed very low numbers of scallops < 80 mm, following the pattern seen in the Young Cove and Hampton sections of the 8-16 mile area.

The older surveys dating back to 1981 can be used to look at the longer term history, before the dramatic recruitment pulse of the late 1980's. These surveys are of different designs and sometimes slightly different areas, but serve to show the larger scale trends in the fishery (Figure 5). The recent densities are still the lowest in this longer time series.

The survey shell height frequencies for the 8-16 mile area are shown in Figure 6 for the 1991 to 1999 surveys. This figure shows the decline in numbers per standard tow and a shift to

smaller sized scallops. It also indicates a low level of recruitment in recent years, with 1999 having the most small scallops that have been seen in the last four years.

Cape Spencer surveys

The contoured biomass estimates for the Cape Spencer area (Figures 7 to 10), and the simple and contoured estimates for the common polygon (Table 7) showed a similar trend to the traditional Digby area, with a decline to a low in 1997 and an increase since then. The increase in the Cape Spencer grounds appears to be larger than that seen in the 8-16 mile area. The contoured biomass estimates gave a larger increase than the simple mean estimate. This was driven by the contouring method used, which takes trends in points and can create "hills" of high biomass between the actual survey stations (Figure 10). The large recruitment pulse that was seen throughout the Bay of Fundy was apparent in the 1989 survey, which had the highest biomass estimate in the series. The biomass in the area then declined to the low seen in the 1997 survey, but showed an increase to 1999.

For the Upper Bay surveys, the contouring of the mean number of scallops <80 mm shell height can be seen in Figures 11 and 12 for the 1986, 1998 and 1999 surveys. The mean numbers and their standard deviations broken down into pre-recruits (< 80 mm shell height), and recruits (≥ 80 mm shell height) for the 1998 and 1999 surveys are given in Table 8. The Advocate Bay bed stands out as having very good recruitment, with a high population of small scallops. Both the Advocate and Cape Chignecto beds support good population densities, in January of 1999 they were at the same densities as the traditional 8-16 mile zone off Digby. They have both dropped down in the September 1999 survey, which may be an indication of fishing pressure, but with the patchy distribution of scallops in this area and the low number of tows the standard deviations are very high. This means that although trends can be interpreted from the data, the differences are not statistically significant.

Logbook data

The effort distribution for 1999 is shown in Figure 13. Most of the fishing takes place in areas covered by surveys. The Class 1 catch and effort in SPA 1 for the 1976 to 1999 period from Full Bay logbooks (Table 9), shows the large recruitment pulse that entered the fishery in 1988 and 1989. This pulse can be seen with the highest CPUE in the time series recorded in

1989. Since then, CPUE has declined to the lowest levels in the time series, with a non-significant increase over the last three years. The Full Bay fleet fishing SPA 1 spent more time outside of the Digby 8-16 mile area than they have in recent years, indicating the improved catch rates in the Cape Spencer and Upper Bay areas.

The catch rates from the Mid and Upper Bay logbooks (Table 10) showed the same trend, with the lowest CPUE in 1997, and a recent non-significant increase.

Port Sampling

The 1996-1998 data from the port samples for the Full Bay vessels in SPA 1 (Table 11), was broken down into three areas to match the breakdown of the surveys: <8 miles from shore above and below Area 4 (off Sandy Cove, Young Cove and Hampton); 8-16 miles off the Sandy Cove to Hampton area; and outside of these grounds. The meat weight distributions for the last three years, for the same three areas, indicated that the fishery was relying on fairly large scallops in the 8-16 mile grounds. The shift in the mode of the scallop sizes from the 8-16 mile grounds in August (Figure 14b) looked like the effort was targeting the incoming year class as it recruited to fishable size in late summer. This also happened to a lesser extent in the 2-8 mile zone (Figure 15) although there were fewer recruiting scallops in this zone. In the area outside the 2-16 mile grounds, the fishery had heavily targeted smaller scallops in 1998 (Figure 16). This was not as evident in 1999, but there was a shift towards smaller scallops in the September sample.

The Mid Bay and Upper Bay port sampling program was initiated this summer and so there are only samples from September (Figure 17). Although the size ranges looked good, anecdotal reports say that the initiation of the port sampling program resulted in a shift to larger sizes being landed.

Exploitation Rate

When the fishery was broken down into periods of activity separated by breaks in landings (Figure 18), a significant relationship ($p<0.05$) was found only for the March 18- May 28 period (Figure 19). The exploitation rate for this period was 24%, corresponding to an instantaneous fishing mortality (F) of 0.27. This time period accounts for slightly over 50% of the catch and about 40% of the effort in the area. Regressions for the other time periods were not significant.

Discussion

All indicators of the stock status in SPA 1 show similar trends. The stock has declined from the historic high of 1988 to a low in 1997, with a slight increase since then. This is seen in both the research surveys and in the commercial CPUE's. Landings in 1999 increased from last year, and are around the levels seen in the early 1980's, although at that time the CPUE's were much higher (Tables 9 and 10). The survey estimates are below those seen in 1984-85, before the large recruitment pulse (Figure 5), but anecdotal evidence says the stock has been this low in the past. At present levels of effort, the removals from the stock in the traditional Digby and Cape Spencer areas, appear to be balanced by growth and a low level of recruitment, with some room for population growth. There is a reduction in the size range in the Full Bay port samples, and indications of heavy fishing on the incoming year class. The fear is that this results in growth overfishing, reducing the potential contribution to landings of the incoming year classes. The landings have increased in the last two years, but these landings are being taken at much lower CPUE's, than in the past, indicating that the stock is at a lower abundance than it was in the early 1980's.

Breaking down SPA 1 into smaller areas, the Upper Bay and Cape Spencer grounds are in better shape and show more recruitment than the Digby Grounds, which have historically been a highly productive area.

The preliminary results from the estimation of exploitation rate indicate that the Leslie method could provide insights into exploitation rate trends for the 8-16 mile block of SPA 1, particularly for those periods of the fishery which account for most of the landings and effort. The results of this preliminary analysis indicate an exploitation rate about 17% above the $F_{0.1}$ level of 0.23, but below the F_{max} (0.35) estimated by Kenchington et al. (1996). When the port sampling data is compared with the time period used for the analysis (Figure 14b), any targeting of patches of recruiting scallops appears to have taken place in late summer, after the period used for the analysis. This concentration of effort on a portion of the grounds being analyzed would go against the assumption of the model that there is an even distribution of effort.

The break in the fishery for March 6-18 does not correspond to the opening or closing of other fisheries and it needs further investigation (Figure 18). Weather may have been a cause. The break in the fishery during the month of June relates to the opening of SPA 3.

Issues to resolve for additional analyses of this area are objective definitions for fishing periods and how to use the survey sampling to estimate mean weight of catch in the fishery.

Conclusion

The outlook for this stock is for low but stable or slightly increasing abundance at the current exploitation rate. In 2000, effort in this area will probably increase over 1999 if the current catch rates are sustained. The main concerns at this time are the low population levels and the heavy targeting of the incoming year class. With the low population levels the possibility of recruitment overfishing is a concern. It is not known how low the abundance can go before the spawning stock is not able to produce an adequate number of recruits to increase the population, even if environmental conditions are good. The targeting of small scallops will result in growth overfishing, catching the scallops at a small size when their high growth rate will contribute more to the population biomass than natural mortality will remove. This wastes the potential contribution to future landings that these small scallops have. The current exploitation rate in the 8-16 mile grounds appears to be greater than $F_{0.1}$, but below F_{max}.

Since conditions at present appear to be stable or slightly increasing, it would be advisable to not increase the allowable catch at this time, and to take steps to protect the incoming year class.

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Table 1. Number of licenses issued and number of active vessels for each license type having access to SPA 1.

	Mid-Bay*		Full Bay		Upper Bay	
Year	Licenses	Active	Licenses	Active	Licenses	Active
1978	n/a	n/a	88	n/a	n/a	n/a
1979	n/a	n/a	83	n/a	n/a	n/a
1980	135	n/a	90	n/a	n/a	n/a
1981	290	n/a	102	68	n/a	n/a
1982	278	n/a	104	66	n/a	n/a
1983	253	n/a	111	77	14	n/a
1984	262	n/a	104	82	14	n/a
1985	269	133	106	70	15	7
1986	238	127	98	67	13	10
1987	214	146	95	80	16	13
1988	211	130	99	91	16	15
1989	211	129	99	96	16	16
1990	210	145	99	94	16	16
1991	210	144	99	93	16	12
1992	206	143	98	90	16	12
1993	208	171	96	99	16	13
1994	209	178	96	92	16	10
1995	209	147	99	94	16	8
1996	208	149	99	96	16	1
1997	207	153	99	78	16	6
1998	207	130	99	75	16	9
1999	203**	133**	99**	69**	16**	14**

*Prior to 1987 these licenses were New Brunswick inshore licenses.

**Preliminary, data to October 1999.

Table 2. Mean number of scallops <80 mm per standard tow by stratum and year for stratified random survey.

	Centreville	Gulliver's Head			Digby Gut	Delaps Cove		Young Cove	
		CV to GH		GH to DG		DG to DC	Parker's Cove		Hampton
1991	30.00	n/a	16.50	4.60	11.64	14.50	6.21	4.17	16.00	16.70
1992	10.83	n/a	13.67	6.75	31.75	68.17	15.50	41.75	13.75	16.83
1993	10.25	n/a	11.88	14.80	9.29	4.60	4.60	3.67	12.50	3.10
1994	n/a	17.00	17.88	27.12	111.93	31.88	16.75	6.50	7.33	3.13
1995	15.25	14.83	16.50	44.88	84.83	36.62	13.70	9.00	1.20	2.10
1996	15.12	7.50	22.00	19.17	23.13	24.88	12.08	12.50	7.60	8.30
1997	17.39	27.72	30.33	54.70	28.01	13.69	5.16	3.14	20.84	10.27
1998	25.51	31.78	42.93	33.81	22.96	13.04	14.74	6.73	9.31	3.49
1999	20.55	23.95	39.47	54.30	51.90	44.05	42.22	7.26	8.06	0.00

Table 3. Mean number of scallops ≥ 80 mm per standard tow by stratum and year for stratified random survey.

	Centreville	Gulliver's Head			Digby Gut	Delaps Cove		Young Cove	
		CV to GH		GH to DG		DG to DC	Parker's Cove		Hampton
1991	339.17	n/a	234.6	217.80	228.32	142.67	154.86	187.00	139.50	172.70
1992	280.67	n/a	262.2	184.50	131.75	135.17	132.50	114.75	125.25	198.50
1993	173.38	n/a	230.1	156.00	163.50	116.20	67.40	84.67	63.20	116.70
1994	n/a	116.8	170.1	145.75	131.43	102.25	77.12	73.57	53.42	38.12
1995	132.12	140.3	146.4	65.12	97.56	58.50	56.90	40.17	18.90	36.70
1996	89.88	28.0	141.0	120.17	76.81	68.25	34.17	50.25	40.10	46.30
1997	69.95	135.1	160.1	139.07	127.37	60.38	27.15	38.07	26.81	26.73
1998	48.58	105.2	97.6	146.76	93.83	85.15	44.14	45.23	40.03	39.39
1999	60.48	119.5	134.4	108.50	115.43	69.59	41.67	46.89	40.91	14.74

Table 4. Mean number of scallops of all sizes per standard tow by stratum and year for stratified random survey.

	Centreville	Gulliver's Head		Digby Gut	Delaps Cove		Young Cove	
		CV to GH	GH to DG		DG to DC	Parker's Cove		Hampton
1991	369.17	n/a	251.1	222.4	239.95	157.17	161.07	191.17	155.50	189.40
1992	291.50	n/a	275.8	191.2	163.50	203.33	148.00	156.50	139.00	215.33
1993	183.62	n/a	242.0	170.8	172.79	120.80	72.00	88.33	75.70	119.80
1994	n/a	133.8	188.0	172.9	243.36	134.12	93.88	80.07	60.75	41.25
1995	147.38	155.2	162.9	110.0	182.39	95.12	70.60	49.17	20.10	38.80
1996	105.00	35.5	163.0	139.3	99.94	93.12	46.25	62.75	47.70	54.60
1997	87.34	162.8	190.4	193.8	155.37	74.07	32.31	41.21	47.65	37.01
1998	74.10	137.0	140.6	180.6	116.79	98.20	58.89	51.98	49.34	42.90
1999	81.03	143.5	173.9	162.8	167.33	113.64	83.89	54.15	48.97	14.74

Table 5. Stratified mean number of scallops per standard tow over all strata for stratified random survey.

	<80	SE	Lower	Upper	≥ 80	SE	Lower	Upper	Total	SE	Lower	Upper
1991	13.5	2.9	8.2	19.8	204.5	23.6	160.5	249.7	218.0	25.8	170.6	269.7
1992	24.0	6.4	12.3	36.0	172.4	16.8	141.4	203.3	196.4	22.0	158.2	235.6
1993	8.3	1.4	5.7	10.8	131.7	12.2	109.2	156.9	139.9	12.6	117.4	166.7
1994	32.0	7.9	17.6	48.6	100.5	9.0	82.8	117.8	132.5	12.8	108.8	159.6
1995	26.7	5.3	17.5	37.7	77.9	9.0	62.0	97.4	104.6	11.4	85.2	127.6
1996	15.7	2.2	14.2	20.9	70.8	7.3	57.1	85.6	86.5	7.9	71.4	102.1
1997	20.4	2.0	16.7	24.6	79.7	6.1	65.0	92.7	100.1	6.7	87.1	112.9
1998	19.8	2.0	15.6	23.7	71.8	6.0	58.9	84.2	91.6	7.1	77.1	104.7
1999	29.6	3.4	23.2	37.5	74.3	6.0	62.8	86.6	103.8	7.0	90.6	118.3

Stratified mean numbers with associated standard errors (Thompson, 1992). Bootstrap confidence limits for 95% CI's (1000 reps, BWR method, Smith 1997).

Table 6. Stratified mean number of scallops per standard tow over all strata for <8 mile part of Eastern Bay of Fundy.

	<80	SE	≥ 80	SE	Total	SE
1991	7.300	3.105	72.100	13.181	75.900	13.956
1992	5.375	3.062	132.100	27.330	137.475	25.949
1993	2.350	0.981	84.950	25.337	87.300	25.140
1994	7.271	2.293	58.542	17.434	65.812	19.081
1995	3.800	1.456	72.100	13.181	75.900	13.956
1996	4.500	3.414	49.200	14.002	53.700	14.579
1997	6.094	2.442	29.897	6.670	35.991	7.332
1998	7.678	2.398	34.788	9.518	42.465	11.573
1999	1.604	1.604	38.868	5.668	40.473	6.537

Table 7. Biomass estimates (kg meat weight) for a polygon of 331.2 square kilometers falling within the surveyed area in all 7 surveys conducted in the Cape Spencer area.

Year	Standard Biomass Estimate	Contoured Biomass Estimate
1987	230,960 ± 47,300	230,329
1989	594,986 ±165,151	550,340
1990	168,493 ± 66,625	145,956
1991	187,325 ± 73,638	193,170
1996	59,840 ± 22,033	52,240
1997	38,173 ± 14,986	38,182
1998	64,361 ± 18,623	62,505
1999	77,682 ± 25,864	98,962

Table 8. Mean numbers of scallops per standard tow for the Upper Bay survey areas. The 1998 survey was conducted in Jan- Feb 1998, the first survey in 1999 was conducted in January, and the second in September.

Year	Survey	Area	Mean	# tows	Std. Dev.	Min	Max
Pre-recruits: <80 mm shell height							
1998	1	Apple River	2.23	30	3.88	0	12.6
1999	1	Apple River	5.79	30	11.37	0	53.3
1999	2	Apple River	7.79	30	20.63	0	75.6
1998	1	Advocate	55.84	8	79.85	0	236.1
1999	1	Advocate	39.30	19	98.26	0	403.6
1999	2	Advocate	120.28	21	225.96	0	869.0
1998	1	C. Chignecto	15.11	23	41.89	0	194.2
1999	1	C. Chignecto	37.65	15	42.71	0	127.5
1999	2	C. Chignecto	34.13	21	93.43	0	422.1
1998	1	Grindstone	0.00	9	0.00	0	0.0
1999	2	Grindstone	0.00	7	0.00	0	0.0
1999	1	Ile Haute	2.01	8	4.11	0	11.3
Recruits: ≥ 80 mm shell height							
1998	1	Apple River	16.91	30	15.92	0	66.4
1999	1	Apple River	26.16	30	28.46	0	108.0
1999	2	Apple River	9.86	30	26.19	0	122.5
1998	1	Advocate	41.25	8	48.29	0	140.5
1999	1	Advocate	71.57	19	108.86	0	376.1
1999	2	Advocate	42.46	21	94.99	0	412.5
1998	1	C. Chignecto	25.86	23	30.00	0	82.7
1999	1	C. Chignecto	87.53	15	60.73	0	163.9
1999	2	C. Chignecto	17.44	21	30.81	0	123.4
1998	1	Grindstone	3.37	9	7.16	0	20.3
1999	2	Grindstone	0.00	7	0.00	0	0.0
1999	1	Ile Haute	22.11	8	28.70	0	78.9

Table 9. Historic trends in Area 1 from Full Bay logbooks. Class 1 data is logbook records for which all catch effort and location information is complete. Total effort is in 1000 h, and is estimated from total catch and Class 1 CPUE. The number of Class 1 log records used to estimate the CPUE is "n". Matching of the database to the new SPA's is not complete so these numbers are preliminary.

Year	# Vessels	Total * Catch(t)	Logged Catch(t)	% Logged	Class 1 Catch	Class 1 Effort (h)	Total Effort (Kh)	Average CPUE	n	Standard Deviation
80	33	179	92	52	92	2,989	5.34	33.5	490	15.2
81	39	215	69	32	69	2,205	6.42	33.5	343	18.9
82	34	167	85	51	82	2,671	5.11	32.7	434	16.0
83	57	283	201	71	174	9,312	14.01	20.2	1,342	9.1
84	59	297	230	78	214	14,297	17.17	17.3	1,918	11.6
85	55	326	239	73	220	16,865	23.12	14.1	1,913	6.9
86	34	266	68	26	63	5,396	21.28	12.5	663	5.8
87	19	561	45	8	44	2,656	23.18	24.2	342	30.3
88	14	756	81	11	64	2,241	21.91	34.5	305	25.3
89	20	1,855	168	9	121	2,968	40.77	45.5	412	30.6
90	13	2,089	266	13	218	8,127	71.54	29.2	871	16.0
91	19	710	151	21	95	4,873	34.30	20.7	498	15.2
92	49	961	730	76	541	26,257	43.09	22.3	2,608	13.3
93	56	602	296	49	176	13,098	43.00	14.0	1,146	5.6
94	61	232	152	66	73	6,268	19.50	11.9	599	4.9
95	63	373	219	59	131	15,284	42.39	8.8	1,302	3.0
96	61	186	110	59	67	8,587	23.54	7.9	843	3.5
97	79	119	113	95	101	15,949	18.03	6.6	1,866	3.0
98	64	188	153	81	136	20,013	26.86	7.0	2,044	2.6
99**	62	194	169	70	161	20,258	23.66	8.2	2,172	2.9

* 1980-1996 estimated by prorating total Full Bay landings by logbook data, accuracy varies with the number of vessels submitting logbooks. 1997 is the first year for which landings were recorded by the new SPA's by Statistics Branch.

** 1999 data to October 10, 1999.

Table 10. Historic trends in Area 1 from Mid and Upper Bay logbooks. Class 1 data is logbook records for which all catch effort and location information is complete. Total effort is estimated from total catch and Class 1 CPUE. The number of Class 1 log records used to estimate the CPUE is "n". Editing of the database is still continuing so these numbers may change.

Year	# Vessels	Total * Catch(t)	Logged Catch(t)	% Logged	Class 1 Catch	Class 1 Effort (h)	Total Effort(h)	Average CPUE	n	Standard Deviation
92	3		22.5		7.8	756		12.25	91	7.94
93	6		33.3		16.2	1,825		9.31	142	4.77
94	15		43.0		38.5	4,215		9.29	438	4.13
95	16		13.3		10.1	1,428		7.34	113	4.41
96	31		12.3		9.0	1,325		7.71	163	6.94
97	47	23.2	24.0	103	22.9	4,815	4,487	5.17	654	5.65
98	42	43.2	44.3	103	42.1	7,042	7,212	5.99	910	2.42
99**	28	64.0	21.5	32	21.3	2,807	8,237	7.77	341	3.43

* 1997 is the first year for which landings were recorded by the new SPA's by Statistics Branch.
** 1999 data to October 10, 1999.

Table 11 continued. Meat weight data from Port Samples from Full Bay vessels in Area 1 for 1996-1999.

Year	Month	N	Mean	Standard Deviation	Min	Max	Count	Total Weight Sampled (g)
Area 1 (Traditional Fishing grounds 8-16 miles Sandy Cove - Hampton)								
96	1	93	11.76	6.42	5.4	36.4	42.5	1093.9
96	2	438	14.43	7.73	3.9	38.3	34.7	6321.4
96	3	348	17.72	8.89	3.6	43.5	28.2	6166.9
96	4	458	16.90	8.14	4.0	52.7	29.6	7741.0
96	5	103	14.37	7.23	3.6	31.2	34.8	1480.6
96	6	366	11.71	5.38	3.4	33.5	42.7	4287.2
96	7	246	13.65	5.78	4.6	30.6	36.6	3357.8
96	8	612	9.93	3.61	4.3	31.4	50.4	6075.7
96	9	37	16.53	4.1	8.9	24.7	30.2	611.6
96	11	328	7.72	2.55	5.0	23.2	64.8	2532.3
96	12	225	10.09	3.65	5.1	34.5	49.6	2270.7
97	2	351	19.73	4.99	5.8	35.1	25.3	6924.4
97	3	755	19.17	5.67	7.0	57.3	26.1	14474.1
97	4	648	17.18	3.61	3.0	30.6	29.1	11132.9
97	5	775	16.98	4.32	4.1	30.9	29.4	13162.5
97	6	473	18.35	3.77	8.7	31.1	27.2	8678.0
97	7	975	14.51	7.00	3.9	52.0	34.5	14144.7
97	8	511	14.40	6.57	6.4	41.8	34.7	7358.4
97	9	827	21.40	8.13	3.7	46.2	23.4	17698.9
97	10	198	22.72	4.38	16.2	37.4	22.0	4497.6
97	12	508	23.61	3.97	16.2	39.8	21.2	11992.8
98	1	230	14.08	9.32	4.2	52.5	35.5	3239.4
98	2	794	16.68	3.71	4.2	34.9	30.0	13240.0
98	3	178	17.81	5.18	5.0	30.7	28.1	3170.9
98	4	879	16.39	3.27	4.9	34.8	30.5	14403.3
98	5	473	17.63	2.85	6.4	34.1	28.4	8338.0
98	6	201	18.72	1.39	15.2	21.8	26.7	3763.1
98	7	503	19.35	2.81	15.0	33.3	25.8	9734.8
98	8	313	19.10	1.78	15.0	23.5	26.2	5976.9
98	9	534	18.38	4.16	7.2	37.5	27.2	9815.1
98	11	45	20.42	5.98	9.7	38.9	24.5	918.8
99	1	51	22.68	3.57	15.3	32.9	22.0	1156.6
99	2	96	20.88	8.64	7.6	52.9	23.9	2004.8
99	3	599	17.87	4.84	8.2	50.8	28.0	10706.7
99	4	841	18.64	5.56	8.2	58.4	26.8	15676.9
99	5	1129	19.27	3.61	6.4	39.8	25.9	21754.1
99	8	257	15.59	4.91	7.3	40.6	32.1	4007.0

Table 11. Meat weight data from Port Samples from Full Bay vessels in Area 1 for 1996-1999.

Year	Month	N	Mean	Standard Deviation	Min	Max	Count	Total Weight Sampled (g)
Area 1 (< 8 miles Sandy Cove, Young Cove, & Hampton)								
96	3	109	22.45	8.68	4.9	37.5	22.3	2446.9
96	4	65	22.07	10.32	5.9	52.5	22.7	1434.5
96	9	35	16.95	3.86	8.0	25.4	29.5	593.3
97	2	446	19.53	7.08	5.3	38.9	25.6	8709.6
97	3	460	18.42	7.24	4.3	49.2	27.1	8471.7
97	4	38	22.09	6.64	9.4	35.4	22.6	839.3
97	5	216	16.04	5.84	4.0	38.4	31.2	3465.2
97	7	249	15.11	6.47	6.1	37.5	33.1	3762.8
97	8	86	23.92	10.41	7.6	44.4	20.9	2057
97	9	183	22.76	8.04	4.7	40.0	22.0	4164.9
97	10	88	25.03	5.95	15.9	38.8	20.0	2202.8
98	9	39	23.79	8.09	9.7	38.8	21.0	927.9
99	4	102	19.76	4.08	11.7	31.6	25.3	2015.0
99	5	147	20.66	5.25	6.7	34.3	24.2	3037.0
99	8	120	16.96	5.78	7.7	32.8	29.5	2034.6

Table 11. Meat weight data from Port Samples from Full Bay vessels in Area 1 for 1996-1999.

Year	Month	N	Mean	Standard Deviation	Min	Max	Count	Total Weight Sampled (g)
Area 1 (Outside Traditional Fishing grounds)								
96	2	284	16.51	7.49	5.1	36.8	30.3	4689.8
96	3	299	15.03	8.12	3.7	39.1	33.3	4494.0
96	4	523	14.17	8.15	3.1	40.4	35.3	7410.0
96	5	550	14.27	6.57	3.2	39.6	35.0	7850.5
96	6	198	20.00	9.47	2.0	51.0	25.0	3960.7
96	7	36	18.60	1.95	14.6	24.1	26.9	669.5
96	8	1152	11.19	5.16	4.0	31.0	44.7	12894.4
96	9	252	17.73	5.01	7.3	32.1	28.2	4467.7
96	10	154	15.41	4.72	5.2	26.8	32.4	2372.8
96	11	150	18.85	8.25	4.3	46.8	26.5	2827.7
96	12	476	9.53	2.13	4.8	19	52.5	4536.7
97	3	194	16.98	7.95	4.0	43.1	29.4	3293.2
97	4	448	15.91	5.22	3.2	34.9	31.4	7127.3
97	5	118	13.24	5.57	2.5	24.4	37.8	1562.1
97	6	119	18.10	2.27	12.9	25.4	27.6	2154.4
98	2	321	13.93	4.48	6.9	30.4	35.9	4472.1
98	3	327	10.46	4.48	4.2	37.9	47.8	3421.9
98	4	145	11.09	5.45	4.1	30.3	45.1	1607.4
98	5	79	10.40	4.68	4.3	25.1	48.1	821.8
98	9	132	13.76	4.55	6.6	30.3	36.3	1816.2
98	12	129	10.36	1.97	7.4	15.4	48.3	1336.5
99	2	166	18.05	6.93	8.3	45.6	27.7	2996.4
99	3	63	15.76	5.58	8.5	31.2	31.7	993.1
99	4	453	18.08	4.92	5.1	34.6	27.7	8192.4
99	5	351	18.22	3.58	9.0	29.1	27.4	6396.9
99	8	169	18.02	4.48	7.5	33.8	27.7	3045.9
99	9	66	15.29	3.08	10.2	24.1	32.7	1009.3

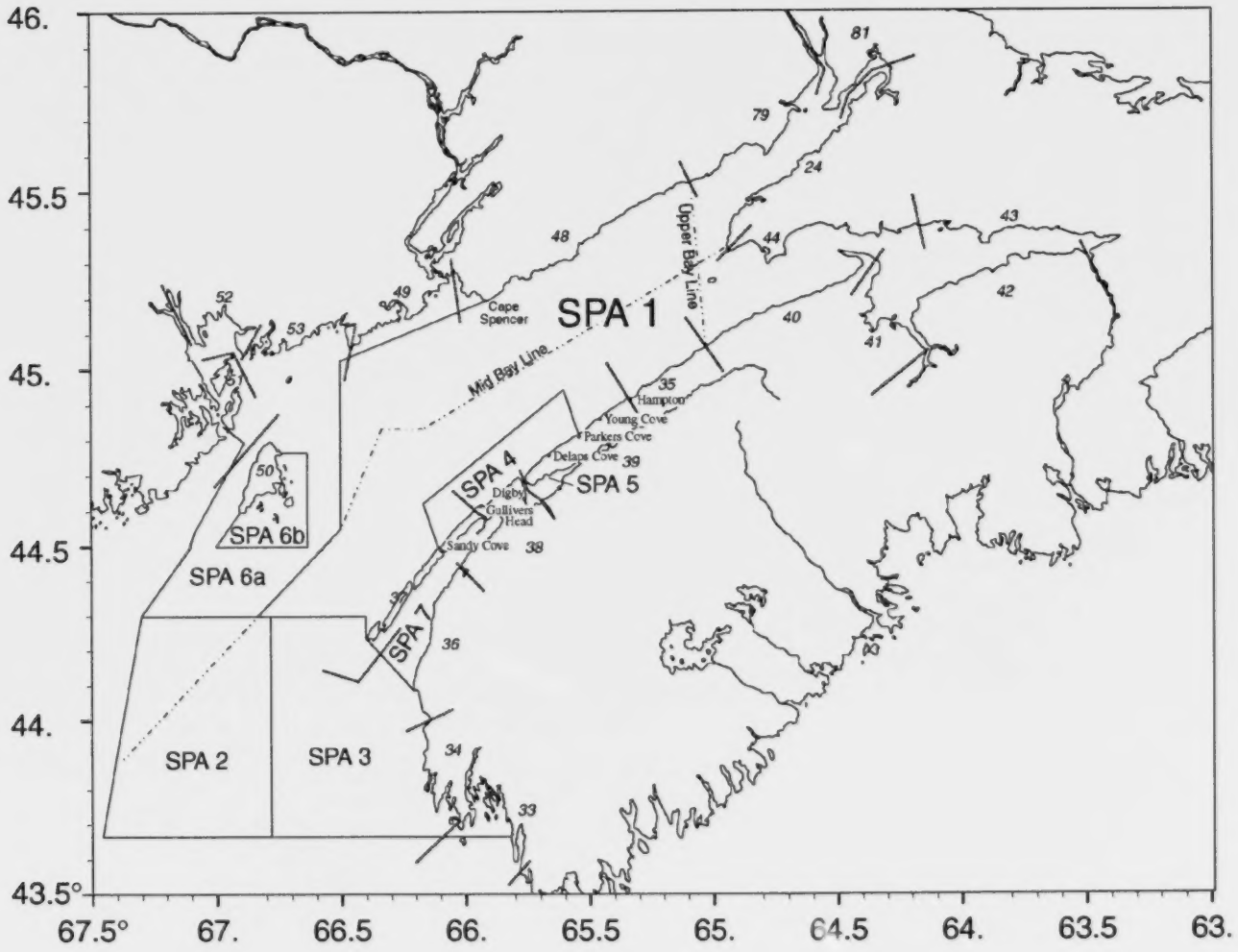

Figure 1. - Scallop Production Areas (SPA's), regulated lines and Statistical Districts in the Bay of Fundy.

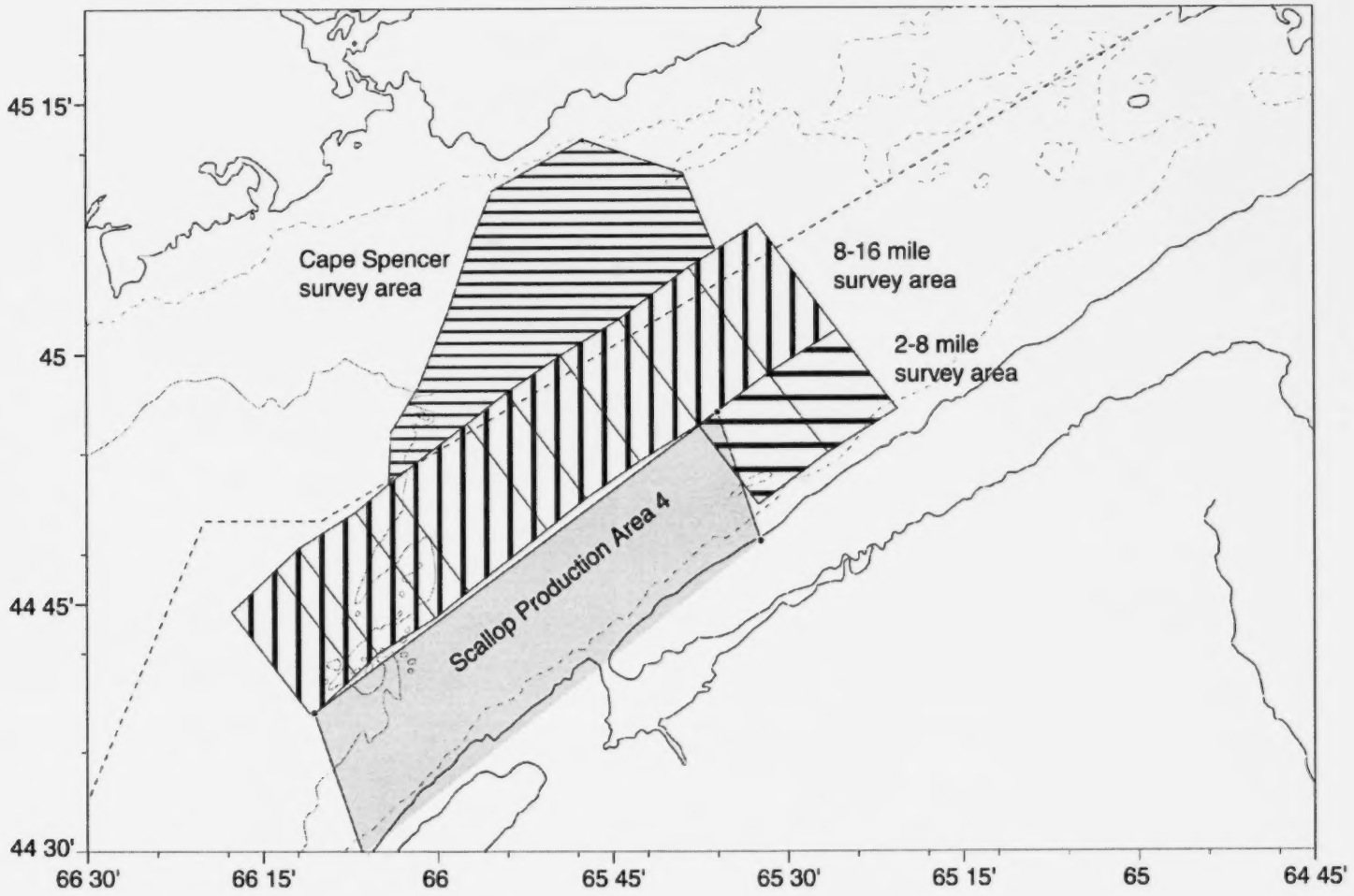

Figure 2. The 8-16 mile and 2-8 mile sections of SPA 1 that have a consistent series of annual surveys, and the Cape Spencer survey area.

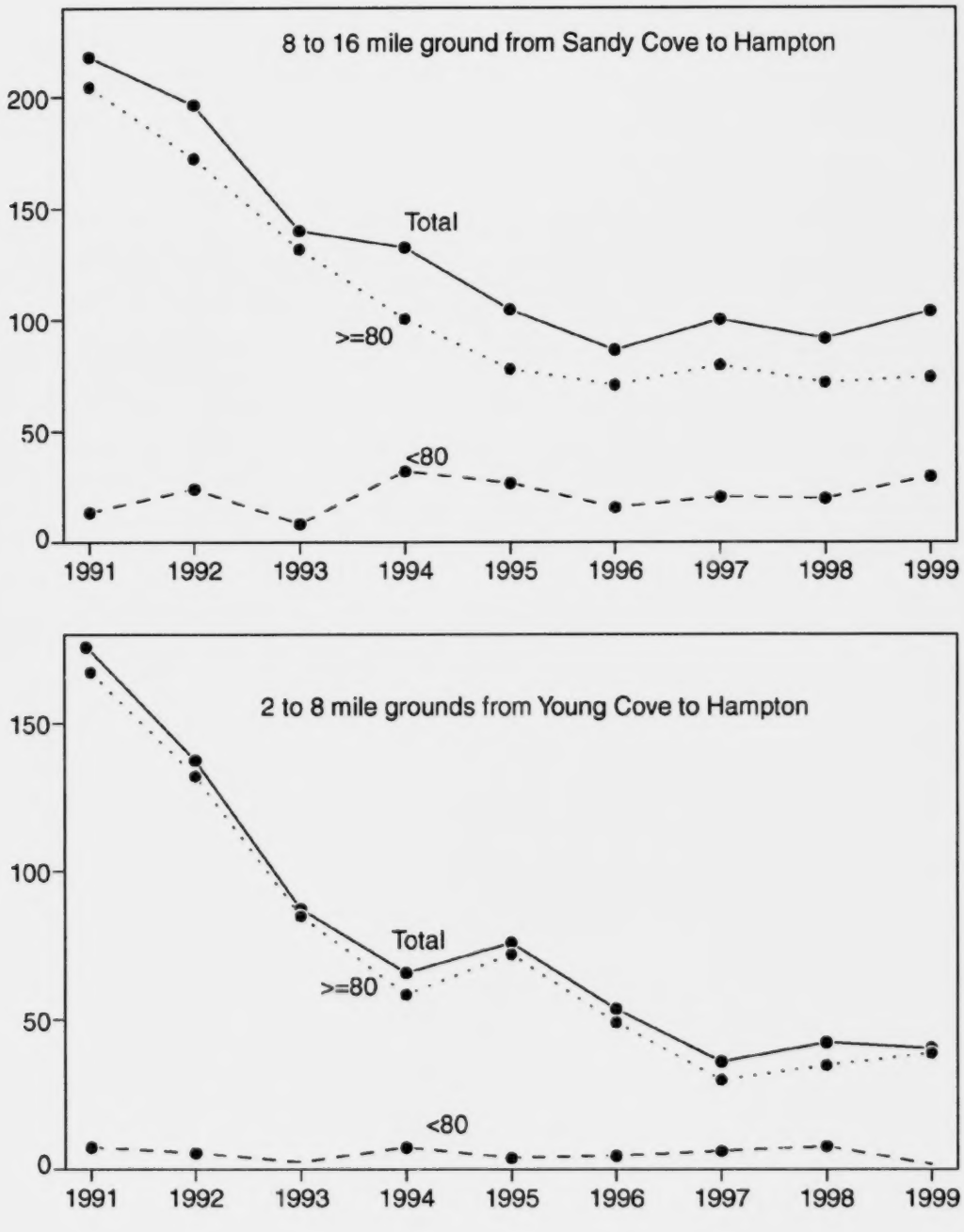

Figure 3. Trends in stratified mean number of scallops per standard tow for the Digby 2- 8 and 8-16 mile grounds of SPA 1.

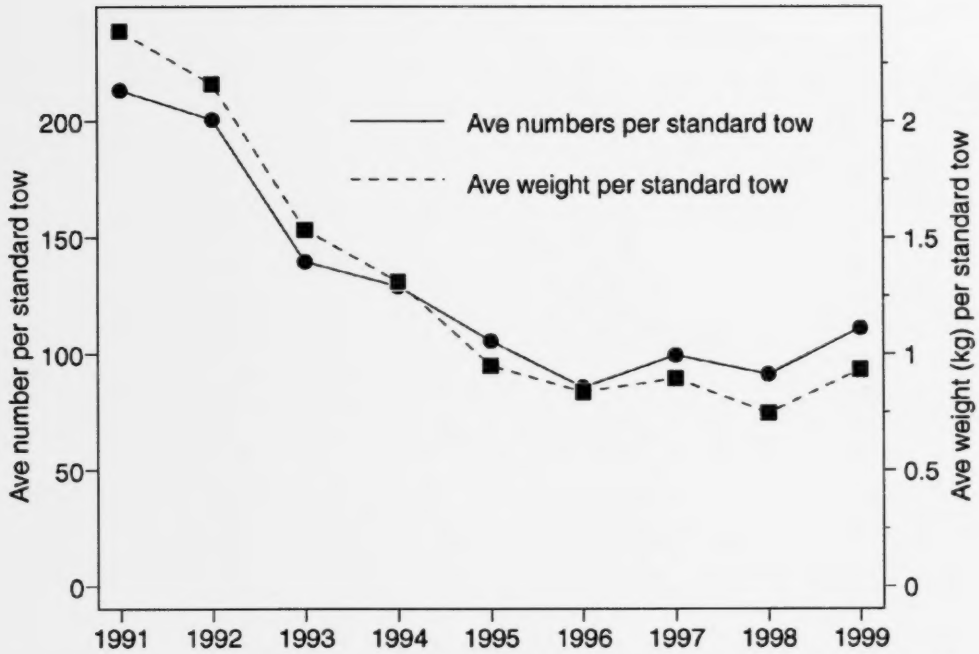

Figure 4. Average total number and meat weight (kg) per standard tow for the 8 - 16 mile area off Sandy Cove to Hampton

Figure 5. Long term trend in survey estimates of scallop densities for the 8-16 mile area from Sandy Cove to Hampton.

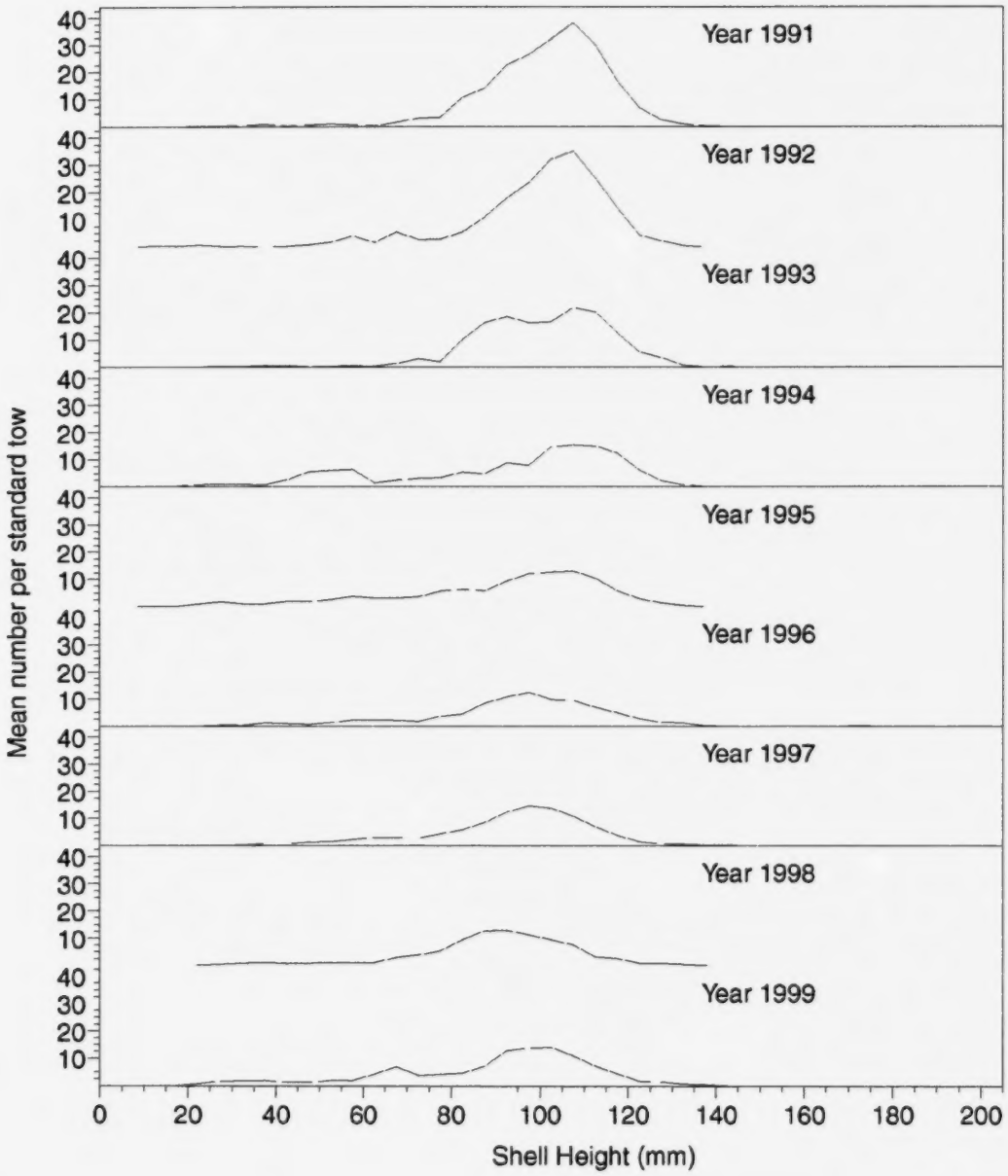

Figure 6. Survey estimates of the mean number of scallops per standard tow at height for the area 8-16 miles offshore from Sandy Cove to Hampton, Nova Scotia.

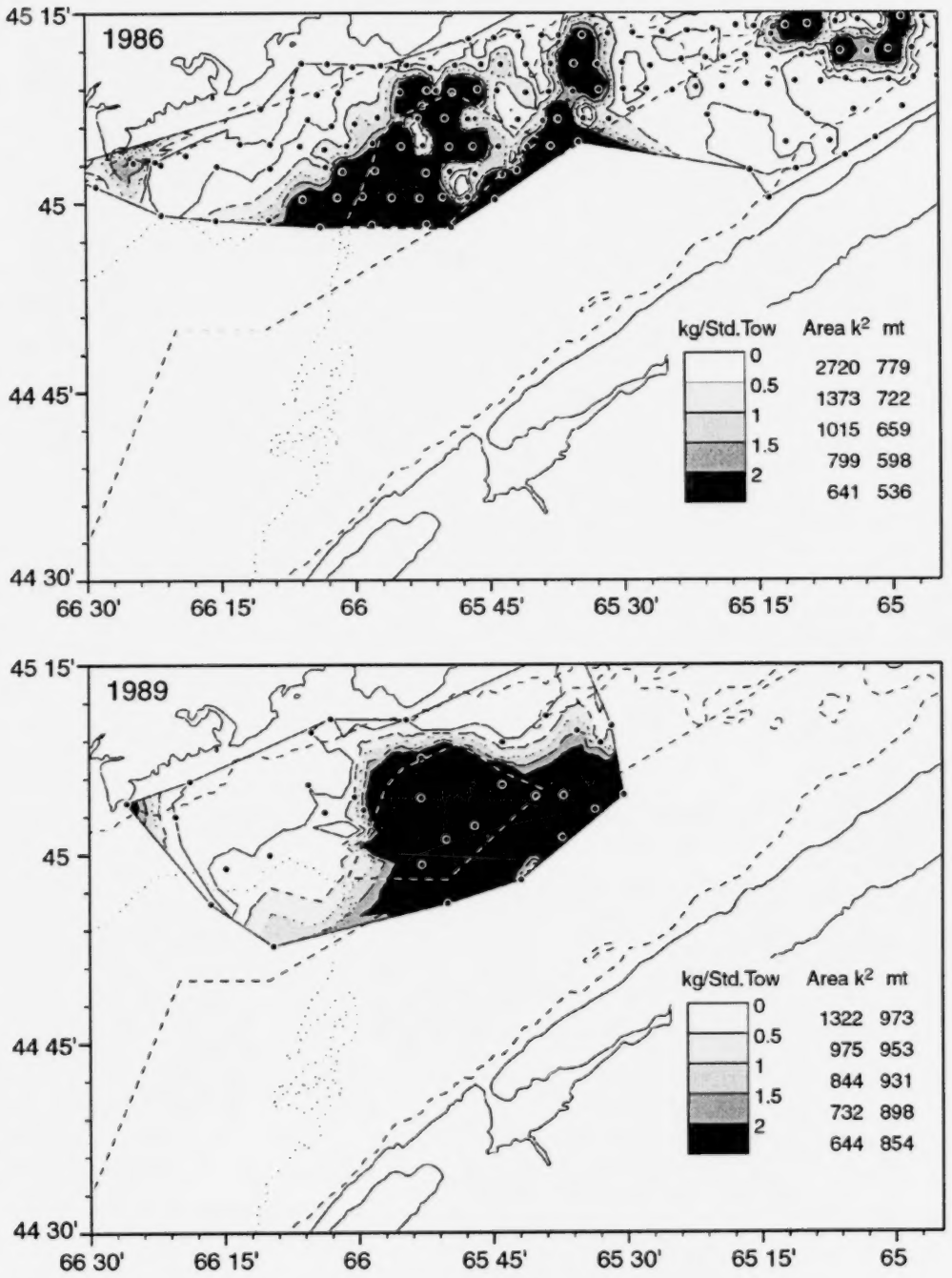

Figure 7.- Total meat weight for scallops ≥ 80mm per standard tow for the 1986 and 1989 surveys. Dashed line shows a polygon common to all seven surveys that was used to examine trends in biomass.

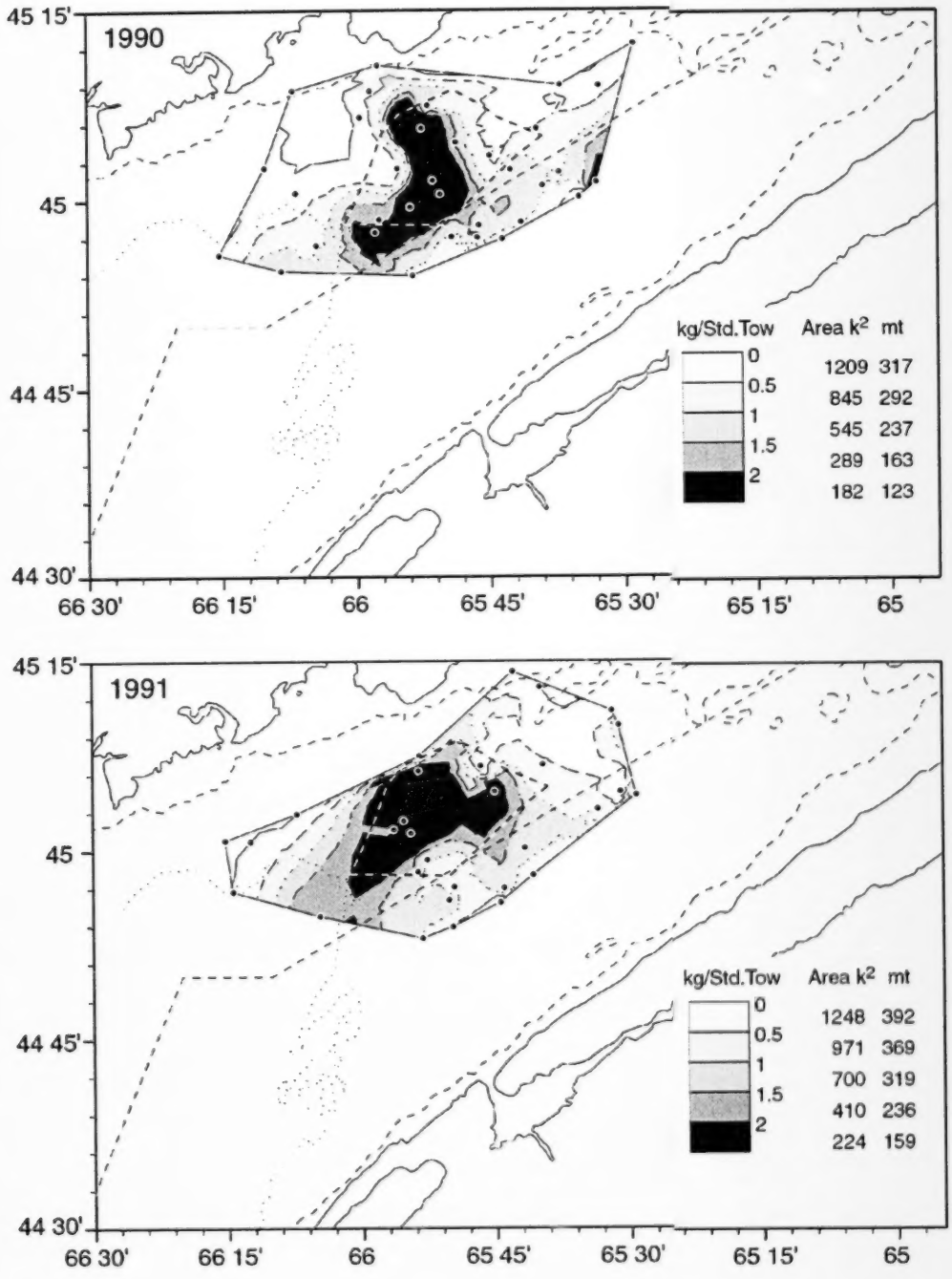

Figure 8.- Total meat weight for scallops ≥ 80mm per standard tow for the 1990 and 1991 surveys. Dashed line shows a polygon common to all seven surveys that was used to examine trends in biomass.

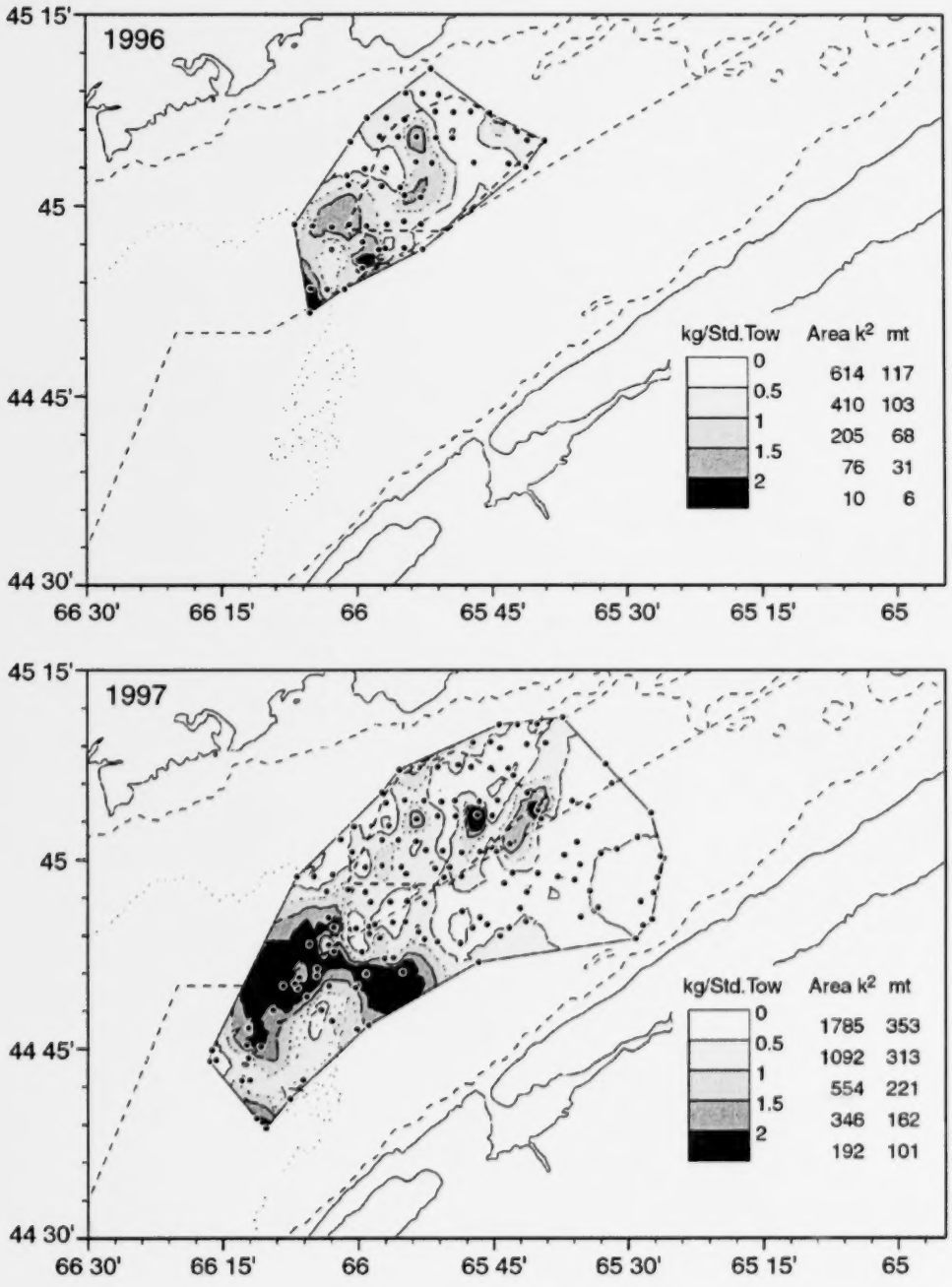

Figure 9.- Total meat weight for scallops ≥ 80mm per standard tow for the 1996 and 1997 surveys. Dashed line shows a polygon common to all seven surveys that was used to examine trends in biomass.

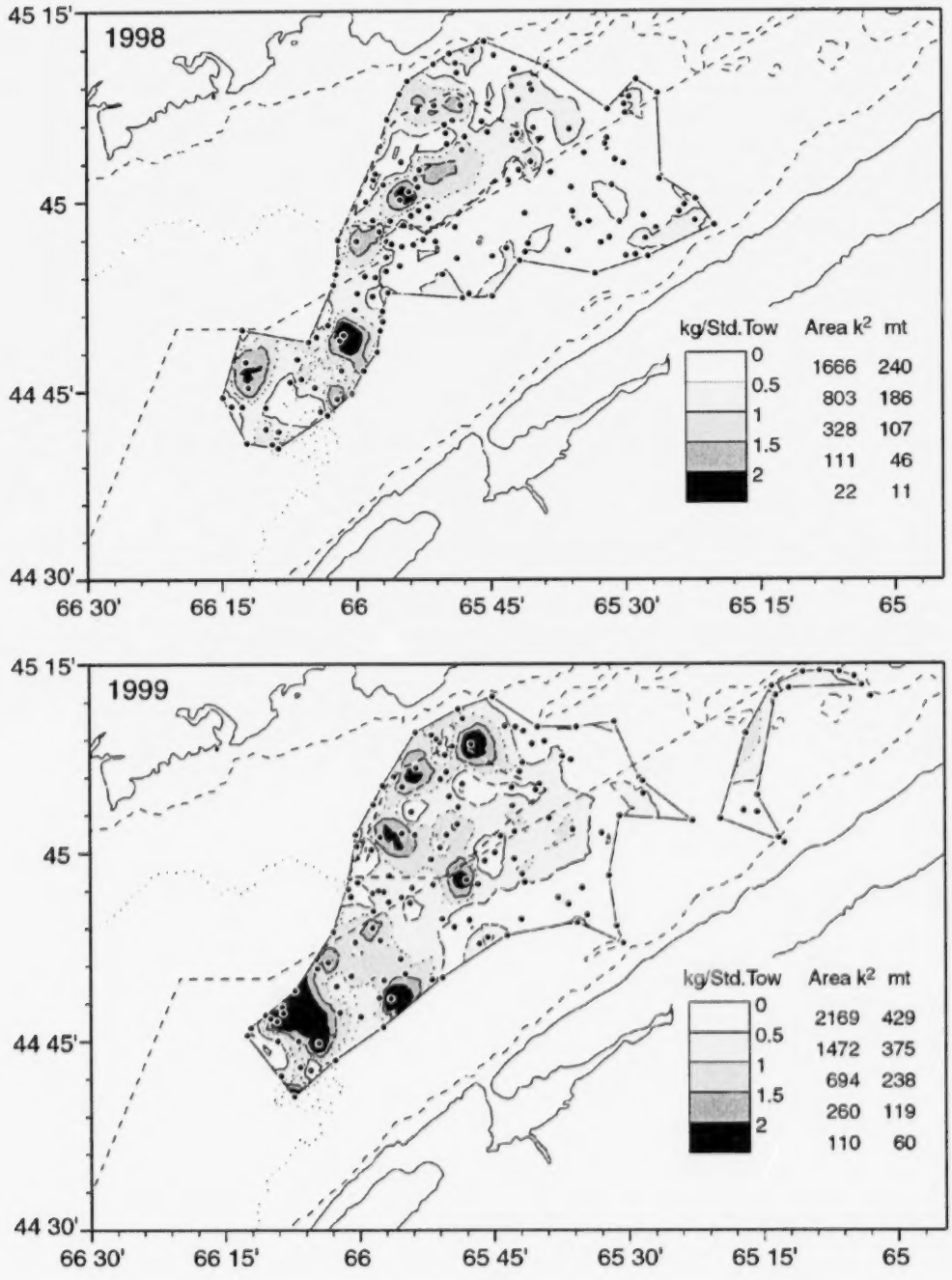

Figure 10.- Total meat weight for scallops ≥ 80mm per standard tow for the 1998 and 1999 surveys. Dashed line shows a polygon common to all seven surveys that was used to examine trends in biomass.

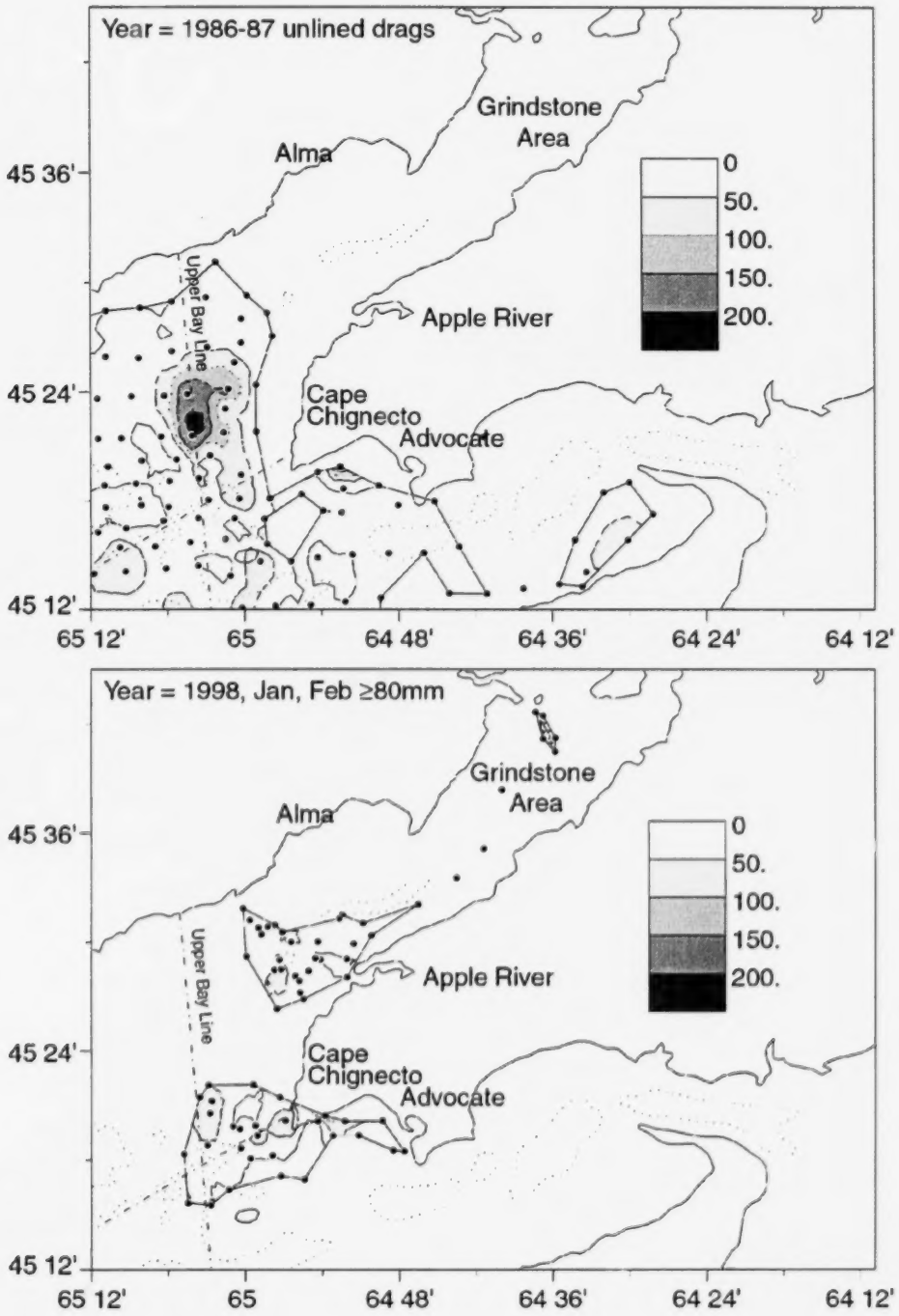

Figure 11. Contour plot of mean numbers per standard tow for the 1986-87 and January-February 1998 Upper Bay surveys.

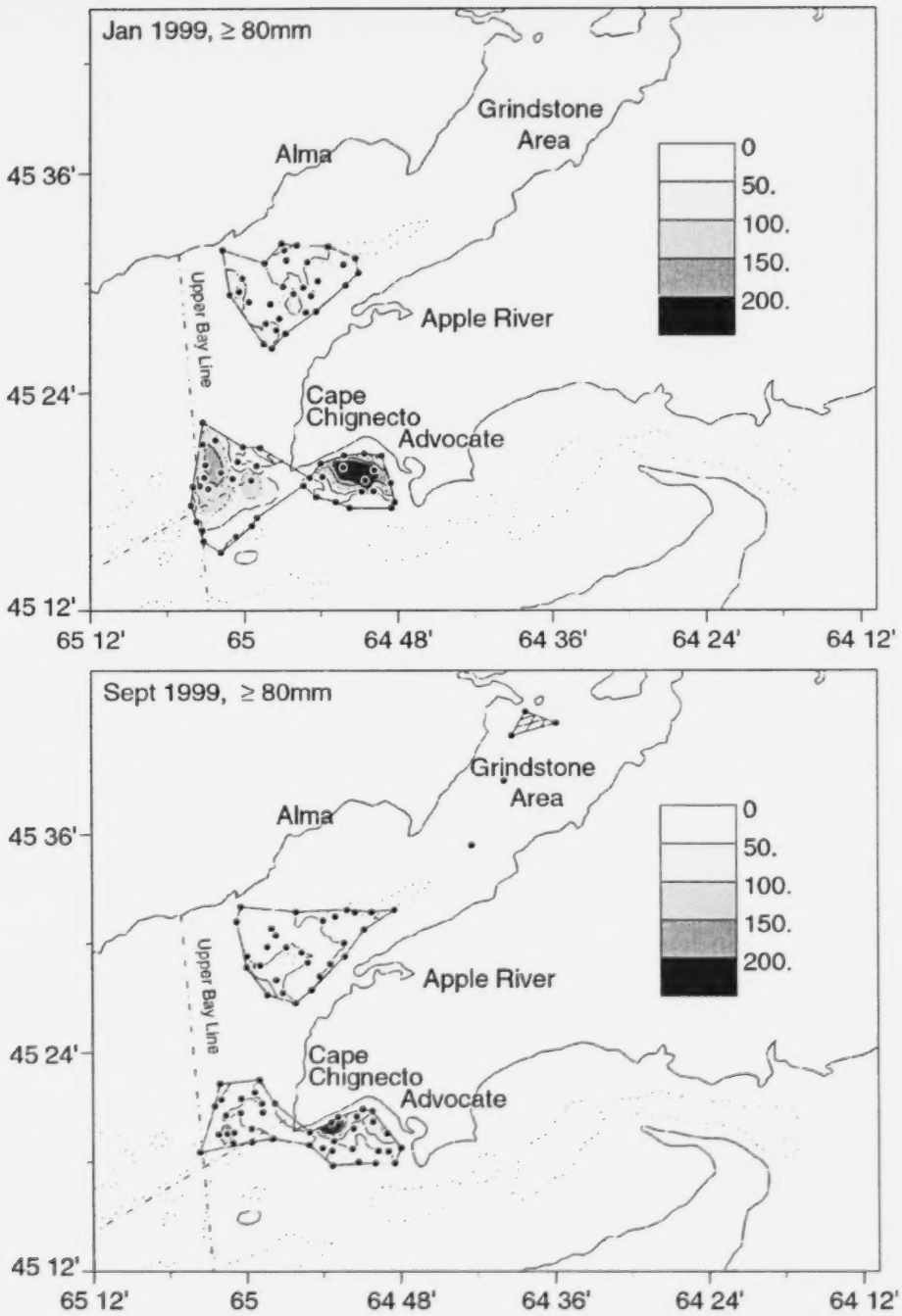

Figure 12. Contour plot of mean numbers per standard tow for the 1999 Upper Bay surveys.

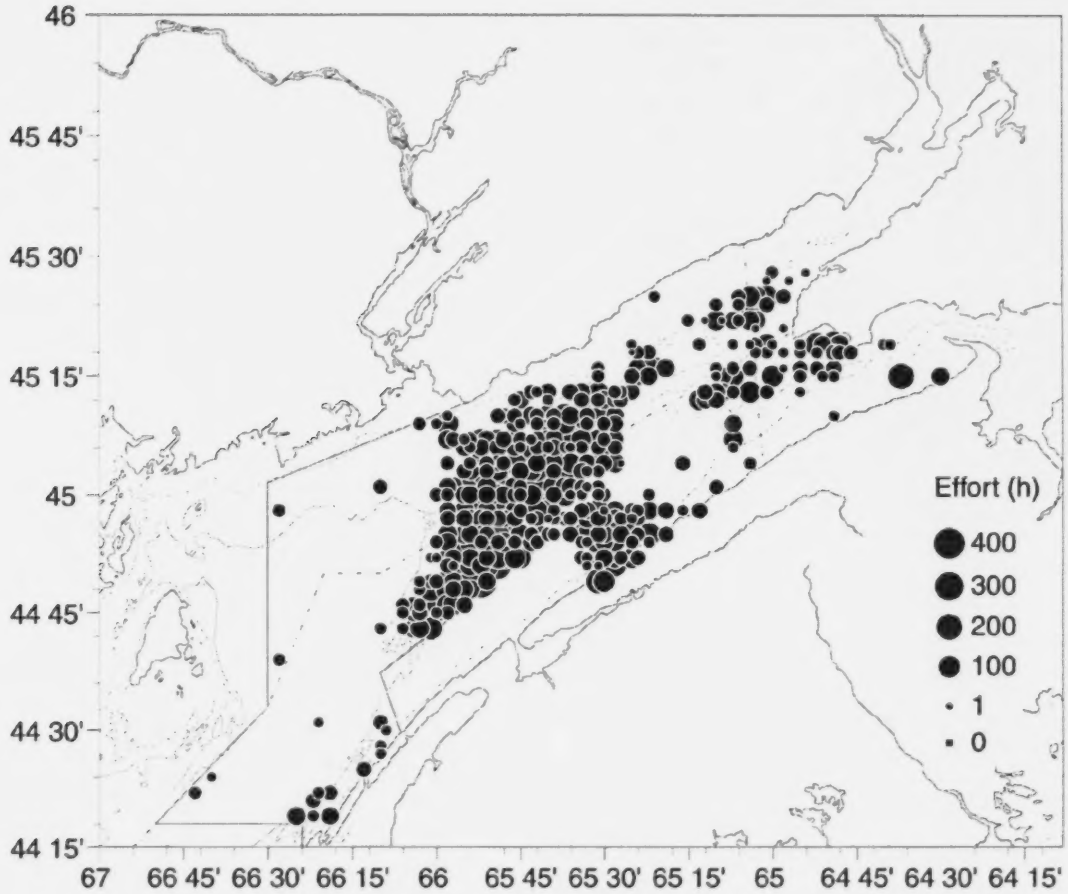

Figure 13. Effort aggregated by one minute squares for SPA 1 in 1999. Data is from Full, Mid and Upper Bay logs Class 1 data, i.e. records having location, effort and catch recorded.

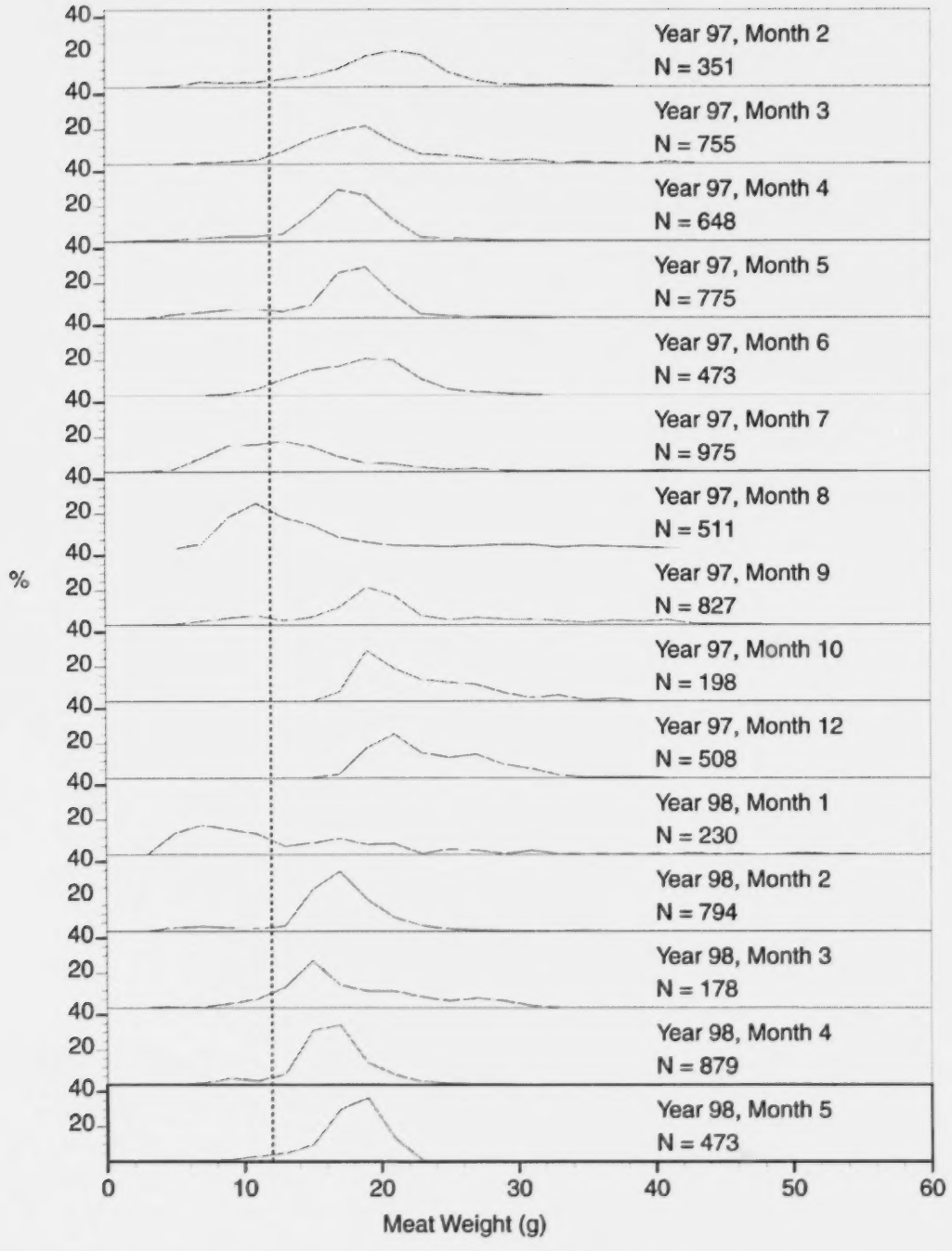

Figure 14a. Meat weight distribution for port samples for vessels fishing in the Digby 8-16 mile area of SPA 1 from Sandy Cove to Hampton.

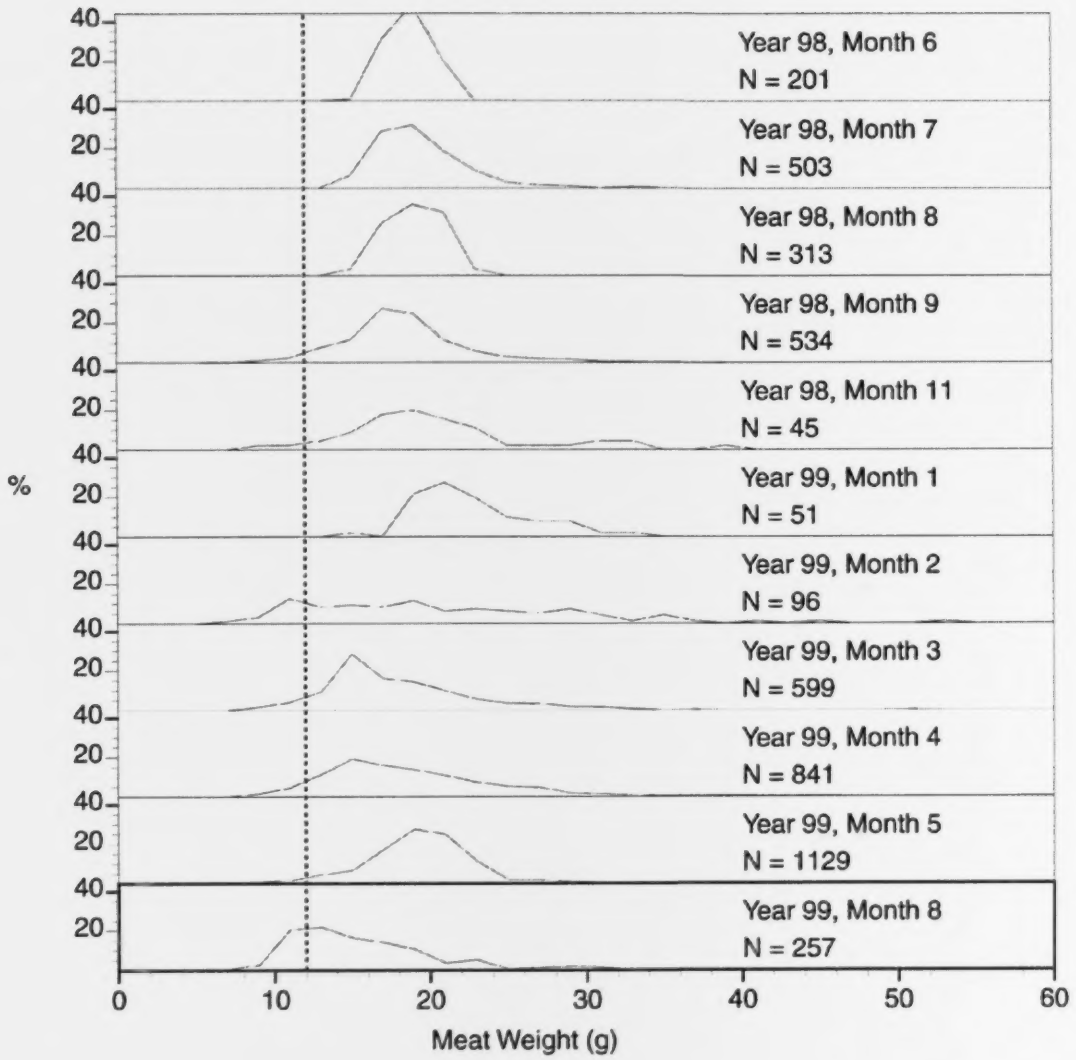

Figure 14b. Meat weight distribution for port samples for vessels fishing in the Digby 8-16 mile area of SPA 1 from Sandy Cove to Hampton.

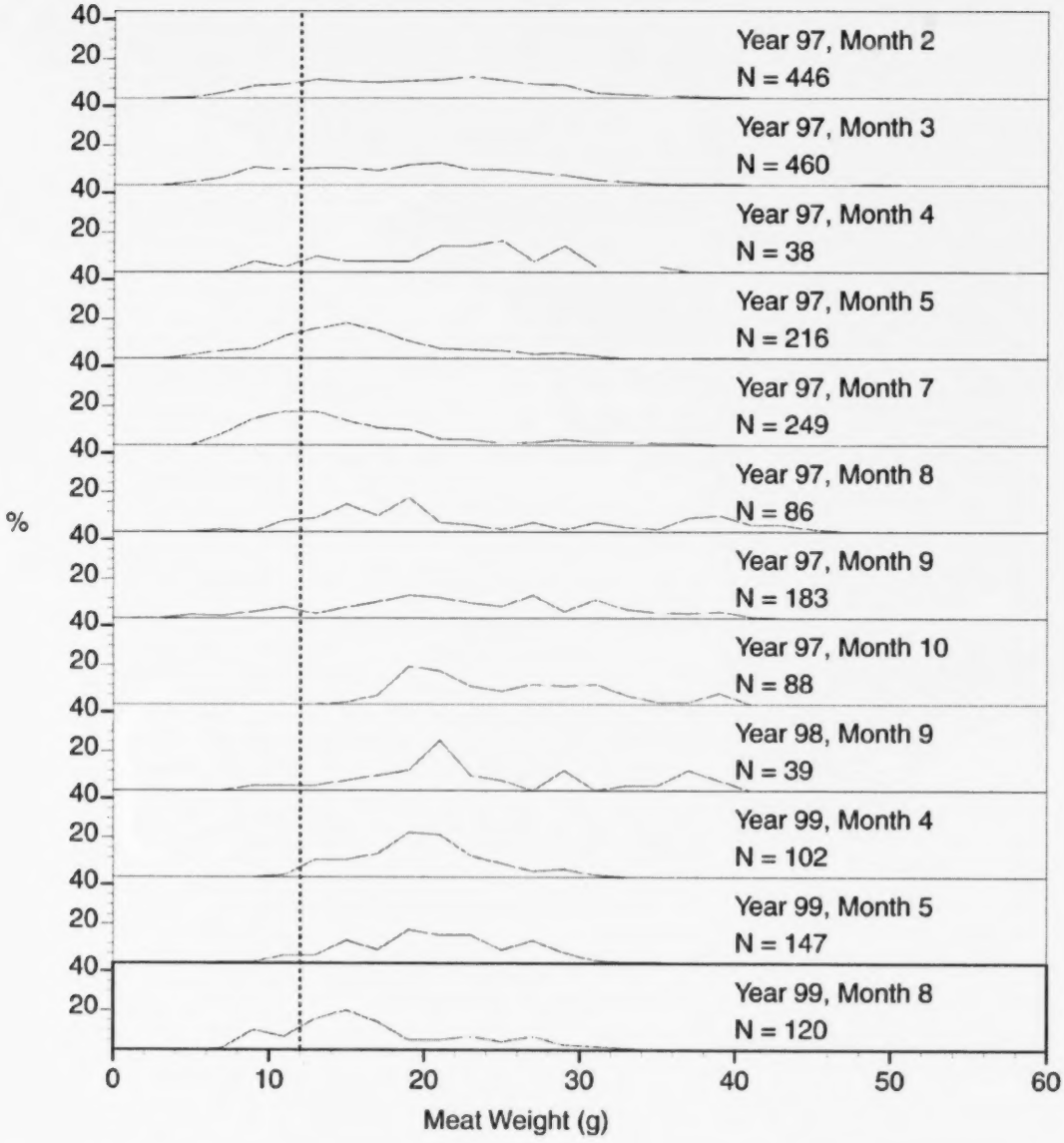

Figure 15. Meat weight distribution for port samples for vessels fishing in the Digby <8 mile area of SPA 1 from Young Cove to Hampton.

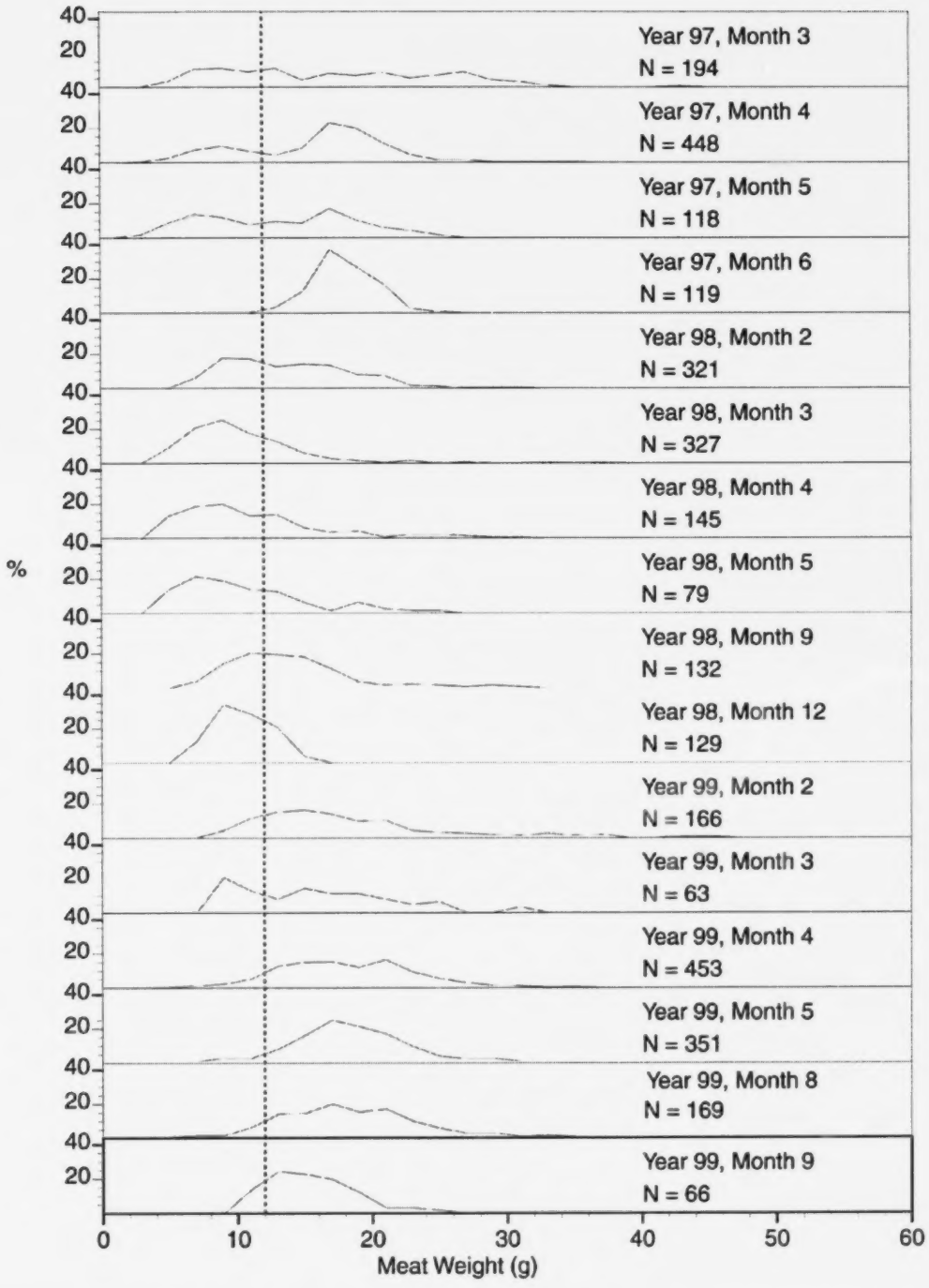

Figure 16. Meat weight distribution for port samples for vessels fishing outside the area 2-16 miles from shore between Centerville and Hampton, Nova Scotia.

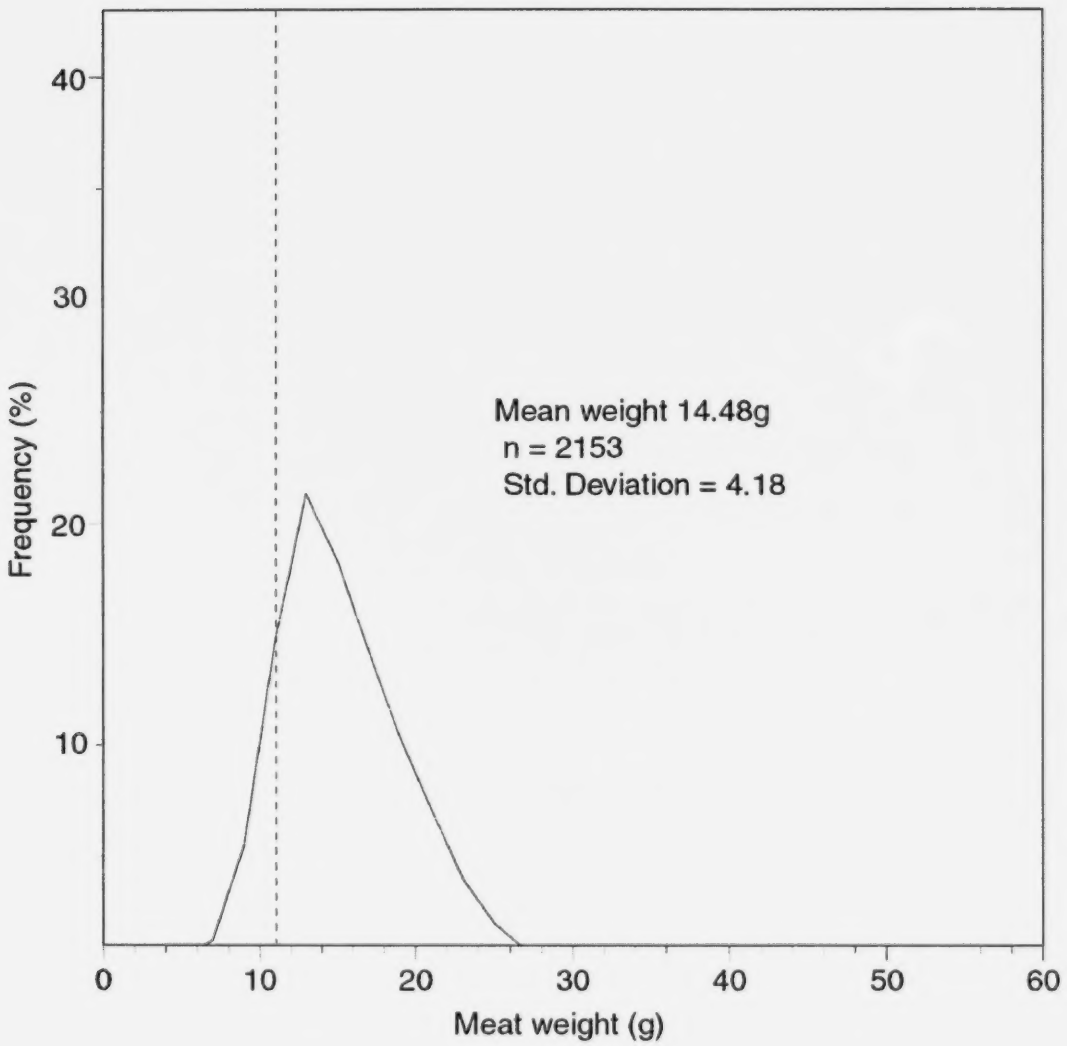

Figure 17. Meat weight distribution for port samples for Mid and Upper Bay vessels fishing in SPA 1 in September 1999.

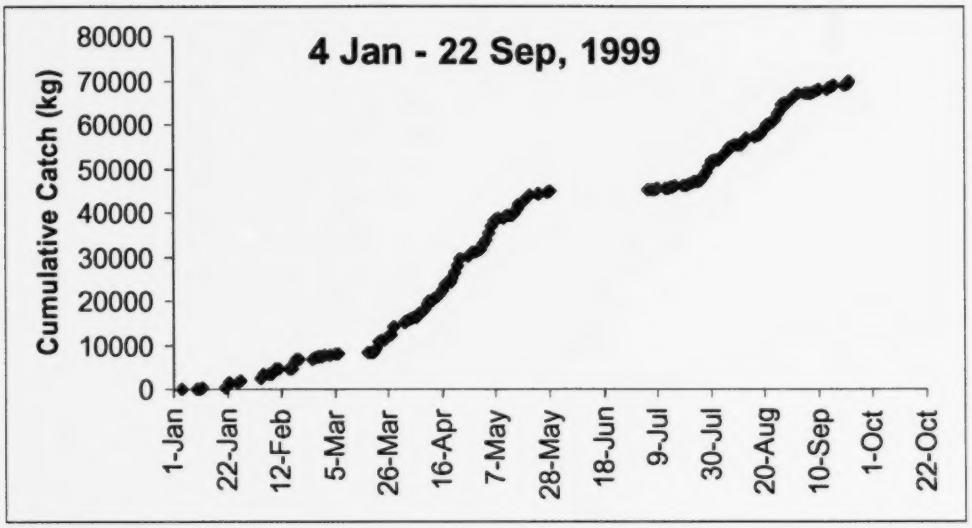

Figure 18. Cumulative catch from the 8-16 mile zone of SPA 1.

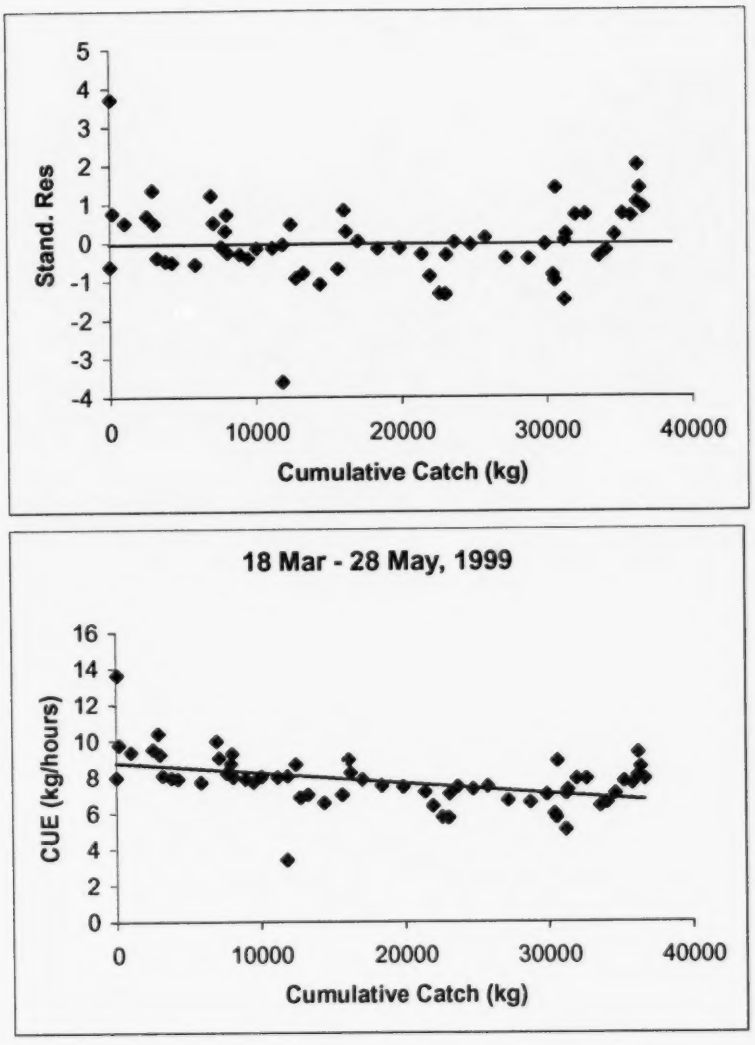

Figure 19. Regression of CPUE against cumulative catch for 18 March – 28 May, 1999 period, with standardized residuals.